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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 711

Contribution from the Forest Service
HENRY S. GRAVES, Forester

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Washington, D. C. PROFESSIONAL PAPER November 14, 1918

LOGGING IN THE DOUGLAS FIR REGION

By

WILLIAM H. GIBBONS, Forest Examiner

CONTENTS

	Page
Object	1
The Region	2
Logging in General	4
Felling and Bucking	30
Primary Log Transportation	56
Loading	154
Railroad Transportation	175
Railroad Inclines	217
Unloading	225
Water Transportation	238
General Expenses	248
Total Cost of Logging at One Operation	252

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OBJECT.

To bring together in systematic and usable form the bulk of the information dealing with Douglas fir logging costs thus far acquired, so as to make it accessible, is the object of this publication. The subject is broad in scope and only the more important features of the Douglas fir sawlog operation, as a rule, are covered. Greatest emphasis is laid on costs,[1] especially costs about which not much written material is available.[2]

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[1] Costs and wages throughout the bulletin are based on conditions prior to April, 1917.

[2] In preparing the publication the writer consulted freely many of the lumber trade journals, especially those of Oregon and Washington; the proceedings of the Pacific Logging Congress, which were particularly helpful; "Logging," by Bryant; "Logging and Lumbering," by Schenck; "Earth Work and Its Cost," by Gillette; and unpublished manuscripts.

Few of the drawings are original, most of them being taken from catalogues and lumber trade journals, especially the Timberman.

The author wishes to acknowledge his indebtedness to all who have aided in any way in the preparation of this work, particularly the following, who reviewed portions or all of the manuscript: J. D. Young, J. S. O'Gorman, Fred MacFarlane, J. P. Van Orsdel, James O'Hearn, H. W. Sessoms, and R. V. Vinnedge, managers or superintendents of logging operations; F. M. Duggan and E. I. Karr, managers of log scaling and grading bureaus; C. S. Martin, C. P. Cronk, S. A. Stamm, and R. H. Shotwell, logging engineers, operating companies; W. T. Andrews, C. H. Woodcock, L. A. Nelson, Austin Cary, and E. C. Erickson, timber sales, Forest Service.

THE REGION.

The Douglas fir region includes practically all of Oregon and Washington west of the Cascade Mountains and a large part of British Columbia. The portion included in the west of Oregon and Washington, which is the part particularly referred to in this publication, has a width of from 70 to 170 miles and a length of 500 miles, embracing approximately 54,000 square miles, or an area as large as the New England States with New Jersey added.

The region varies greatly in its topographical makeup. In every part of it there are valleys, rolling hills, high tablelands, rivers, lakes, and mountains. A considerable proportion is mountainous, especially the timbered areas.

While great diversity is found in topographic features, similarity in the timber, as to size and volume of stand, has resulted, speaking generally, in the use of uniform logging methods. For this reason it has not been necessary to any considerable extent to consider special methods in connection with particular sections.

Mild winters are characteristic, and logging may be continued throughout practically the entire year.

COMMERCIAL SPECIES.

Douglas fir, the principal tree, is one of the most important American woods. It was early shipped to different parts of the world for masts and spars, and was the first tree in the region to be manufactured into lumber on a large scale. It ranks second in the United States in point of production, being very extensively used in the building trades by the railroads in the form of car and bridge material, ties, and piling, and by many manufacturing plants. As a structural timber it is not surpassed, and for a long time it was most widely used and known in this capacity. Originally covering, in forests of great density and almost absolute purity, the greater part of the foothills and lower slopes of the Cascade Mountains and the Coast Range, it now comprises about 70 per cent of the standing timber in the region. It is a gigantic tree, under favorable conditions having a diameter of from 3 to 6 feet. Trees 8 or 10 feet in diameter are to be found.

Western red cedar is one of the most durable woods grown in this country. It was first utilized for shingles about 30 years ago, and now supplies the bulk of the shingles manufactured in the United States. In addition, it is extensively used for poles, piling, posts, and siding. Its commercial range in this region is roughly confined to western Washington and northwestern Oregon. It forms about 10 per cent of the stand in the Puget Sound country and about 2 per cent in northwestern Oregon. In the region of its greatest abundance and best growth it has a higher stumpage value than any of the species with which it is commonly associated.

Sitka spruce, being used extensively in the manufacture of aeroplanes, is attracting more than ordinary attention at present. Its chief assets are strength and lightness, and lack of color and odor. For these reasons it is of great value in box and cooperage manufacture. It ranks with cottonwood as the best pulpwood in the region. Spruce confines itself to the vicinity of the coast, extending only along arms of the ocean and the courses of streams.

Western hemlock ranks next to Douglas fir in point of quantity, comprising about 10 per cent of the timber in the region. It is not confined to the forests of any one portion. On the west slope of the Cascade Mountains and the east slope of the Olympics and Coast Range it occurs most commonly in stands in which Douglas fir is the principal species. Here the percentage of hemlock varies from 5 to 60 per cent of the stand. On the western slopes of the Olympic Mountains and the Coast Range it is found with Sitka spruce, western red cedar, and Douglas fir, at times forming more than half of the stand.

After a thorough trial, hemlock wood has been found to be of excellent character. Unfortunately, its merits are too little appreciated as yet, the result being a weak demand for hemlock lumber and relatively poor utilization of hemlock in the woods. Western hemlock is utilized for rough lumber, all the principal planing-mill products, many of the manufactured products, pulpwood, piles, posts, and ties. It ranks fourth in the region in point of production. As time goes on this species will be in increasing demand for pulpwood.

There are several other trees in the region that will ultimately prove of great commercial importance. Noble fir, for example, has been utilized to a small extent within the last few years. It is a mountain tree, which has long, clear boles that yield a high percentage of clear lumber.

AMOUNT AND OWNERSHIP OF TIMBER.

Though more than 90 per cent of the region is potential timberland, no such area was timbered when white men started to utilize the land in 1850. Insects, winds, and fires set by lightning had denuded a perceptible area, and the Indians kept a small portion burned over. At present, about 70 per cent of the productive area in Oregon and Washington is timbered. This timber, with that in parts of British Columbia, constitutes the finest body of general-purpose timber known to exist. Large trees rise to a height of from 175 to 250 feet, or even more, and form very dense forests, which yield from 25,000 to 60,000 board feet per acre, and occasionally as much as 100,000 feet. Small tracts frequently cut out more than this.

The ownership, acreage, and volume of the timber in western Oregon and Washington are given approximately in Table 1.

TABLE 1.—*Ownership, acreage, and volume of timber in western Oregon and Washington.*

Ownership.	Area.	Per cent of total timbered area.	Stand, billions of feet b. m.	Per cent of total stand.
	Acres.			
National forests	10,816,000	48−	162	22−
Privately owned	8,991,000	40+	450	61+
State and other Government land	1,000,000	4+	40	5+
In litigation	1,700,000	8−	85	12−
Total	22,507,000	100	737	100

LOGGING IN GENERAL.

INDEPENDENT LOGGERS.

To the general rule that logging and lumber manufacture are conducted as one business the condition in the Douglas fir region is a striking exception. Not far from 50 per cent of the timber is logged by operators engaged solely in logging, who cut their own timber and sell their logs in the open market. The independent logger gets out most of the timber delivered to the waters of Puget Sound and the Columbia River; and he is an important factor at Grays Harbor, but plays a relatively small part at Willapa Harbor. Whether he has a permanent place in the lumber industry of the region no one can confidently predict.

So far, independent logging has seemingly worked out well, both from the standpoint of the capital invested and from that of the service performed. The independent logger, devoting his entire time and talents to logging, finds it easier to be efficient. As he disposes of his logs in the open market, the size of his operation is not limited by the capacity of a mill. As soon as business conditions make operating unprofitable, the independent logger, as a rule, can shut down. With the possible exception of difficulty in disposing of low-grade logs, he is not at a disadvantage in any respect at present. The opening up of new tracts of timber on a large scale, however, would probably change conditions.

The percentage of timber logged by contract is small.

SIZE OF OPERATIONS.

Logging operations vary in size, their daily output ranging from 40,000 to 500,000 feet.

An operation may consist of one or several camps. In any case, however, the camps are near each other, have a common ownership, and are supervised by the same head.

A camp may be made up of one or more sides, a side consisting of the crew and machinery necessary to handle the logs from one yarding engine. Where a number of engines are found at a side, each side may constitute a camp. A camp may include as many as four sides when only one or two engines are used at a side. It is difficult to generalize regarding this matter.

The output of a side, varying as it does with the yarding output, ranges generally from 40,000 to 80,000 feet per day.

STEPS IN AN OPERATION.

Powerful steam machinery is the most prominent feature of the logging operations of the Douglas fir region. The timber is large, the ground rough, rugged, and covered with bushes, so that some form of power logging is necessary. Logging with animals is confined for the most part to the logging of ties, bolts, piles, and poles.

The investments in logging plants are strikingly large. At present more capital is invested for improvements and equipment in Pacific coast logging operations than in similar operations in any other region of the United States, taking output into consideration. Therefore operators have to plan their work a long time in advance and be conversant with the most approved methods, not to mention mastering the maze of details in any enterprise conducted on a large scale.

The work in every department is specialized, each requiring a few technically trained men and a large percentage of skilled workmen. This is made necessary by the size of the operations, the complexity of the methods and equipment used, and the timber-utilization problems encountered. Trees 6, 8, or 10 feet in diameter, standing on rough, steep ground, are felled and converted into logs in such a way that a minimum of waste results; and logs, some of them scaling 10,000 board feet and weighing 30 tons, are dragged with great dispatch over the ground or swung down steep slopes and over deep canyons on overhead cables.

The term "logging," as commonly used, covers all the work of handling logs from standing timber to the sawmill. It can be divided into several steps. These, as well as the methods and equipment used, are not always distinctive, so that the subject is very involved and a classified treatment is essential. In this bulletin each step is treated separately in the order in which it occurs, which is as follows:

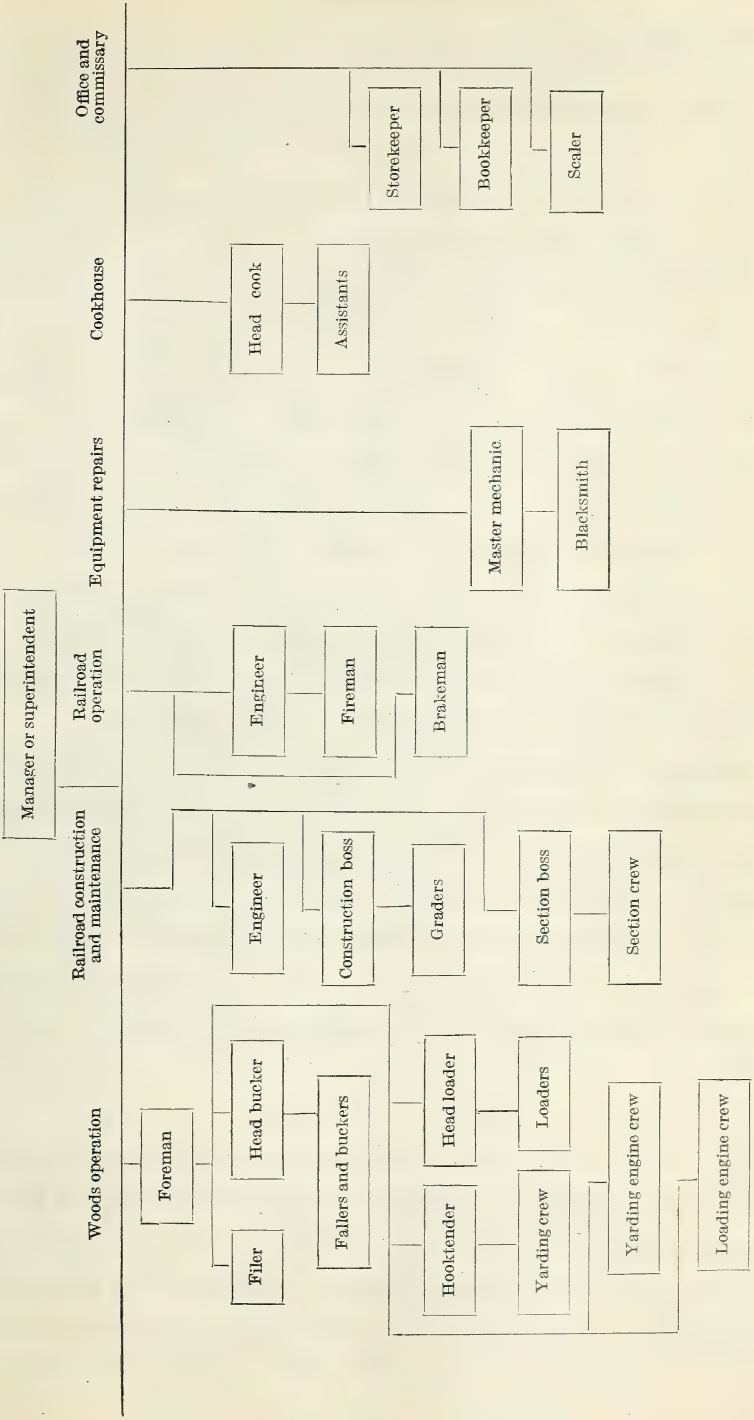
1. Felling and bucking.
2. Yarding, swinging, and roading.
3. Loading.
4. Railroad transportation.

ORGANIZATION OF THE PERSONNEL.

In the large operations a manager or logging superintendent, who spends all or a part of his time in the woods, is responsible for the logging and, if the operation is an independent one, for the sale of the logs. The camp foreman is next in responsibility. He may supervise directly all the different departments of the operation or just the work of delivering the logs to the landings. In some cases a logging engineer, responsible to the superintendent only, plans and constructs the railroads.

The usual division of responsibility is shown in the following diagram:

Organization of a Pacific coast logging operation.



LABOR.

The success of logging operations in this region depends in a large measure on the character, supply, and efficiency of the workmen; for the work is done under changing conditions, standardization of methods and output being to a great extent out of the question. Even under the most favorable conditions the skill, initiative, and reliability of most of the workmen count largely in the cost of logging.

On the other hand, the character and duration of the work and the conditions under which it is performed are not such as to attract, develop, and hold the type of workmen that logging operators hope to secure. The camps are in the woods; they usually afford very little opportunity for leading a normal life; and, with few exceptions, they do not satisfy certain normal and wholesome desires. The industry has to depend on a woods force composed in large part of restless, dissatisfied bachelors—old and young—largely foreign born, a large portion of whom constantly shift from camp to camp via the larger centers of population—men who are not in the way of doing the best for themselves or their employers.

This state of affairs, which is largely the logical consequence of our industrial and social development, is by no means confined to the logging industry. And the logging industry has not been slower than most industries to see that it does not pay; that even enlightened selfishness urges the bringing about of better conditions.

How to impress on the minds of the workmen the necessity and desirability of constant application and how to make the conditions as to hours, pay, and surroundings such as to induce the better workmen to continue with the industry, to attract desirable workmen from other fields, and the like, are difficult questions. A number of companies have attracted wide notice within the industry by remarkable and far-reaching provisions for the comfort, instruction, and recreation of their workmen, and by a mode and scale of payment enabling the employee to realize the largest earnings possible to his individual capacity. Most operators have modified former methods in some respects.

LENGTH OF EMPLOYMENT.

The length of time woods workers are required each year is governed by the methods of logging and the demand for logs or lumber. In the Douglas fir region many operators can continue logging throughout practically the entire year, and in no case for less than nine months. In recent years, however, the demand for forest products has been so weak that forest laborers in the region are fortunate when they secure seven or eight months' employment in a year.

No result of the depressed condition of the lumber industry is more deplorable than this. The short employment period each year and the peculiar social conditions are doubtless largely responsible for the fact that woods laborers of the region as a class are not as steady and efficient as they might be.

METHODS OF EMPLOYMENT AND PAYMENT.

There are three principal methods of hiring those of the men who are not hired directly by the camp foreman. The most common, perhaps, is through the regular employment agencies. Some of the larger operators employ their own agents. When a company uses enough men to justify the expense of a private agent, this usually proves the most satisfactory arrangement. In some instances several companies join in maintaining an agent, but that plan has often proved unsatisfactory because of a feeling that one company was favored more than another. In other cases the crews are kept up almost entirely from men who apply for work either at the camps or at the city offices.

So far labor unions have played only a small part in the logging industry of the region, and that in an indirect way. The natural independence of the woods worker and the fact that strong or normal demand for woods labor over long periods is unusual are probably the principal reasons why he has not affiliated with labor unions. Furthermore, living conditions in the camps are improving and relatively good wages are the rule. However, stronger efforts for the organization of a loggers' union are made each year.

Most of the men are paid by the day, the operators charging them for board. The monthly men, such as foreman, bookkeepers, cooks, and locomotive crews, as a rule, have their board in addition to their monthly wages.

Comparatively little contract work is done. In a few cases felling and bucking and railroad grading are contracted, and, less often, the delivery of the logs from the stump to the landing in the case of an out-of-the-way chance.

A system of bonuses, a modification of the wage system, is being tried out by a number of operators.

The men are usually paid once a month or on the termination of their work. Either bank or time checks are used. In most cases the time checks are taken at their face value by the merchants of the surrounding towns, the exception usually being in the town or city where the company has its offices and where the men may exchange the time or bank checks for cash.

WAGES.

The following is a list of the wages—average, high, and low—paid by logging companies on the west side of the Cascades in Oregon and Washington during the last six or eight years. The wages designated high and low do not represent extremes. For example, the wages paid at times during 1914 and 1915 averaged lower than those given in the list. Wages have remained at the same general level, rising or falling with fluctuations in the demand for labor. If there was any change, skilled labor received a little less toward the close of this period, common labor a little more. During slack times the wages of common labor are cut more heavily in proportion than those of skilled labor.

TABLE 2.—*Average wages paid during the six years ending in 1916.*

Position.	Wages per day.			Position.	Wages per day.		
	Average.	High.	Low.		Average.	High.	Low.
Head bucker or timber inspector	$3.50	$3.75	$3.25	Master mechanic	$4.50	$5.00	$3.00
Head faller	3.50	3.75	3.25	Carpenter	3.50	5.00	3.00
Second faller	3.25	3.50	3.00	Car tinkerer	3.00	3.25	2.75
Bucker	3.25	3.50	3.00	Pole road construction foreman	4.50	5.25	4.00
Filer	3.75	4.00	3.50	Pole road construction men	2.75	3.00	2.50
Hooktender	5.25	6.00	4.50	Landing construction foreman	4.00	4.50	3.50
Rigging slinger	3.50	3.75	3.25	Landing construction men	2.75	3.00	2.50
Chokerman	3.25	3.50	3.00	Locomotive engineer	4.00	4.50	3.75
Chaser	3.25	3.50	3.00	Locomotive fireman	3.00	3.25	2.75
Swamper	3.00	3.25	2.75	Conductor or head brakeman	3.50	4.00	3.25
Sniper	3.00	3.25	2.75	Brakeman	3.25	3.50	3.00
Signal man	2.75	3.00	2.50	Section foreman	3.25	3.50	3.00
Yarding and road engine engineer	3.50	3.75	3.25	Section men	2.50	2.75	2.25
Yarding and road engine fireman	2.50	2.75	2.25	Railroad construction foreman	4.50	5.50	3.50
Wood buck	2.50	2.75	2.25	Railroad construction men	2.50	2.75	2.25
Head loader	4.25	4.75	3.50	Rafting, or boom, foreman	3.50	4.00	3.25
Second loader	3.50	3.75	3.25	Rafting, or boom, man	3.25	3.50	3.00
Gypsy, or spool, tender	3.00	3.25	2.75				
Loading engine engineer	3.25	3.50	3.00				
Loading engine fireman	2.50	2.75	2.25				
Pump man	2.75	3.00	2.50				
Blacksmith	3.75	4.00	3.50				

Certain employees who, as a rule, are paid by the month are not included in the above list. The monthly salaries of these men are about as follows, plus board:

Foreman	$125 to $250
Bookkeeper	75 to 125
Timekeeper	75 to 100
Storekeeper	75 to 125
Logging engineer	75 to 125
Scaler	75 to 125

BOARD.

Operators in the region feel that a well-fed man gives better service and is more likely to be satisfied with his work, so that a well-conducted boarding department is one of the features of most operations.

The quality and variety of the food are of a high order. Fresh meats, vegetables in season, and canned fruits and vegetables of a good quality are to be found in practically all the camps. Wherever possible the men come in to all meals. A lunch in the woods occasions much grumbling.

Boarding departments, as a rule, are self-supporting, the weekly charge in 1916 amounting to $5 or more. Cooks are paid from $50 to $150 per month, depending on the size of the crew. Camps of 60 men or more usually have an assistant cook, the kitchen help being figured on the basis of 1 man in the kitchen for each 30 men in the crew.

CAMPS.

It is good to be able to record that no greater advance has been made in any of the departments of the operation than in the housing and care of the workmen, and that the progressive loggers of the Pacific Northwest have been leaders in the industry of the whole country in providing model camps.

A few years ago camp buildings were crude structures, having few, if any, conveniences. Unfortunately, in many camps there is still much room for improvement. Fairly satisfactory living quarters, however, are the rule, the best camps being well constructed of dressed lumber and equipped with individual beds or bunks, private lockers for clothing, hot and cold water, steam heat, and like accommodations. Furthermore, camps of the latter class have a pleasing appearance, due regard being given to the design and arrangement of the buildings and the color of the paint used. Operators as a class do not seem to have given sufficient attention to camp sanitation.

Three types of camps are used, the portable camp on wheels, the portable camp on skids, and the stationary camp. All three prove satisfactory, and each is adapted to certain conditions.

(1) *Camp on wheels.*—Mr. C. S. Martin, who is employed as a logging engineer by one of the largest operators on the Pacific coast and who has had an opportunity to study the different methods of housing the men, discusses the modern complete camp on wheels as follows:

> The advantages of camps on wheels are coming to be widely recognized. The first cost may be greater, but when one takes into consideration the following arguments in their favor it will be found that they prove cheaper in the long run, giving the camps a life of from 10 to 20 years, which is, I believe, conservative.
>
> (*a*) *Insurance.*—In case of fire the camps can be moved at a few minutes' notice.
>
> (*b*) *Depreciation.*—Ten per cent should cover both depreciation and upkeep, a much smaller percentage than had to be charged to the old shack camps, which cost nearly as much to tear down and rebuild as to abandon.

(*c*) *Wages and time saved in moving.*—We moved Camp No. 3 this spring; yarded 249,000 feet the day before moving, 269,000 feet the day we moved, and 257,000 feet the day following the move. The move was about 4 miles. The men took dinner in the old camp and supper in the new without losing time in the yarding. As the camp carries its own 1,000-gallon water tank, it could give the men their usual accommodations on a switch or siding if necessary. This was a camp of 160 men. I have known of instances where such a move would keep most of the crew busy for several days or at least one day. A camp of this size costs about $350 per day to operate, so a little time saved makes quite a showing.

(*d*) *Class of men attached to a camp of this sort.*—A good many men in the woods would rather work in a camp where the living and working conditions are right than in another camp where the wages may be a little higher but the living conditions poor. We do not give the camps all the credit for this by any means. A large part of it is due to the foreman and his ability to handle the better class of men. The fact remains that in Camp 3 during the time it has been operated [1914 and 1915], we have had more "top" men (who were foremen and booktenders in normal times) than in any other camp of which I have knowledge. And it shows up in the work. Operating in a scattering "show," we got from two to four cars more per day than we had counted on, which was due very largely to the class of men we had in our rigging crews.

(*e*) *Distance from work.*—As the camp can be moved more cheaply than a more permanently located camp, we can move oftener and keep the men nearer their work. There are often small, more or less isolated pieces of timber to be picked up now and then, and a camp on wheels is very handy in such instances.

(*f*) *Cost of clearing site.*—Requires a smaller camp ground, and less clearing. A space 60 feet wide by 400 feet long will serve for a three-side camp.

(*g*) *Cost.*—Such a camp costs from $9,000 to $12,000, depending on the material put into it. In terms of a one-side camp this amounts to from $3,000 to $4,000 a side, which is reasonable even when considering the cost of the old-time board shack camps. One-side camps on wheels have been built in our country at a cost of $4,000 to $7,000, everything except the bunk cars and possibly the blacksmith shop being the same for a small as for a large camp.

The camp referred to by Mr. Martin as Camp 3 consists of 12 cars set in 2 rows, 6 on each side, with a walk between. Movable steps connect this walk with the various compartments. The whole camp, inside and out, is well lighted with electricity. The cars are set close to the railroad track, so that they can be steamed out when the need arises, the steam being furnished by a locomotive.

The cars are mounted on trucks rated at 60,000 pounds capacity and having 3¾-inch journals. The framework on which the floor joists rest consists of six 6 by 12 inch longitudinal sills surmounted by 10 by 14 inch body bolsters and 10 by 12 inch end sills. These are reinforced by six 1¼-inch truss rods extending the length of the car. All cars but one are 14 feet wide and 60 feet long. The other car, the cook house, is 14 feet wide and 36 feet long. The cars are sided with 6-inch drop siding and painted yellow with white trimmings. The cook house, dining cars, and all cars used as living quarters are ceiled on the inside with beaded ceiling, painted and varnished.

Windows and doors are sliding. A cupola roof raised about 3 feet above the main roof gives room for ventilating transoms. The main roof is shingled, and the cupola roof is covered with corrugated roofing.

The kitchen is modern in every respect. Many hotels do not have the modern cooking equipment which is to be found in it. It has a triple range with hood, two double-deck, zinc-covered serving tables on casters, built-in drawers and bins, a raising closet, hot-water tank, etc. Coal is used for fuel.

Two of the cars are used for diners, one at each end of the kitchen car. This arrangement simplifies the handling of food. These cars have a seating capacity of 175, with sleeping accommodations for the cookhouse crew in the end of one. Heavy crockery dishes are used because they are easy to clean and have no enameled surface to chip off into the food.

A car stationed immediately opposite the cookhouse and connected by means of a bridge is used for a warehouse and meat shop. This arrangement places the supplies needed in the kitchen close at hand. On the top of this car is a water tank, which supplies water by a gravity system to all parts of the camp. The meat room is in one end of the storeroom and just under the water tank. It is zinc lined and has sawdust-filled walls.

Five of the cars are used for sleeping quarters, each being divided into three compartments, accommodating 10 men each, or 30 men to a car. Each compartment is equipped with five double iron bunks with springs and mattresses, a sink with hot and cold water, shelves and hooks for clothes, steam heat, electric lights, and individual soap dishes. This division of the sleeping cars makes it possible for the men to form congenial groups.

One of the cars is used for a bath, dressing, and drying room. The bath room is equipped with six shower baths and a dressing room. The operator furnishes the soap. At the other end of the car is a drying room for the men's clothes. Batteries of steam coils laid on the floor under racks furnish sufficient steam to dry garments thoroughly in one and a half hours.

A reading and writing room 14½ by 22 feet is situated at one end of the warehouse, where daily papers, magazines, and writing material are kept.

Another car, besides furnishing sleeping rooms for the office force, is used as a general camp office and commissary. A portion of this car is used for the company's civil engineer. The engineer's room, which has skylights, is fitted with a drafting table, map racks, an instrument closet, and a double bunk for the engineer and his assistant.

The blacksmith and machine shop is installed in another car. The electric light, power, and heating plants are also located in the same car. Steam heat is furnished by a 35-horsepower internal-fire-return tubular boiler. Electric light is generated with a 4½-kilowatt, 200-light dynamo. Oil, stored in a 1,000-gallon tank, is used for fuel.

The toilet is as well built as the rest of the camp, also as well lighted. It has screened ventilators and covered seats so arranged that they close automatically when not in use.

The hog pens are situated at the headquarters camp, all the swill being hauled from the camp in sanitary covered cans.

(2) *Portable camp on skids.*—The buildings of a portable camp on skids are moved from one location to another on logging cars or by means of donkey engines. They must be of a size that can be loaded readily on the cars. Strength in construction is an important factor, because of the frequent handling to which they are subjected. This type of camp has proved more satisfactory than the ordinary permanent camp. With the exception of the initial cost, it has no advantage over the camp on wheels, and it has some fundamental disadvantages.

In the case of one company, the living quarters are 10 by 14 by 7½ feet, with a 3-foot gable. These cabins are substantially constructed, are sided with dressed and matched lumber, and have a rubberoid roof. There is a door in front and two sliding windows at the rear. For convenience in moving, the cabins are set on runners. The interior of each is furnished with three single iron bunks, a stove, and like accommodations. The approximate cost of each cabin was $50. Iron bunks, mattresses, a stove, etc., raise this figure to $75. At this rate, the living quarters for 99 men cost $2,475. The efficient life of these cabins ranges from 7 to 10 years. Twenty-three cabins, all logging tools, equipment, etc., were loaded and hauled a distance of 3½ miles in 18 hours. In another case similar cabins 14 by 30 feet and accommodating eight men were constructed for $100. To furnish one of these cabins with double iron bunks, mattresses, a stove, etc., cost about $50. At this rate accommodations for 96 men cost $1,800.

The cost of the dining room and kitchen varies, depending on the type and size of building, also on whether it is of permanent or take-down construction. One stationary dining room and kitchen, large enough for 90 men, cost $900; another, large enough for 200 men, cost $1,500. These figures include tables of all kinds, bins, etc. The dining room and kitchen equipment—range, cooking utensils, dishes, etc.—cost $600.

(3) *Stationary camps.*—Some of the most ably managed companies prefer large camps, not constructed to be moved, in which

from 150 to 300 men are accommodated, the men being taken to and from their work by train when working at a distance. The labor policy of the operator usually has something to do with the type of camp adopted. Where the policy is to encourage married men who want their families near them large and more permanent camps are used. Superintendents who do not permit families in or near the camps most often favor portable camps.

In one operation the permanent camp for single men consists of two large two-story buildings of modern design. One of the buildings is used for a bunk house for 100 men. This is plastered and painted and kept clean and sanitary. It is well ventilated, electric lighted, and has hot and cold water and a modern sewerage system. In each of the rooms there are four single iron beds, four lockers, four chairs, a table, and a droplight. The washroom at the rear of the building has a concrete floor. It is large enough to accommodate 10 men at one time.

The cookhouse, which is on the first floor of the other building, consists of a well-equipped kitchen and a large well-lighted dining room with a seating capacity of 125. Above the cookhouse is the recreation hall, fitted with two pool tables, card tables, reading and writing tables, a barber shop, and a bathroom.

The camp has graded streets, lined with neat cottages. There is a church, school, meat market, and some other shops besides the company store.

This is the ideal type of camp, supplying, as it does, pleasing and sanitary living quarters and surroundings for both single and married men. Unfortunately there are few camps of this type in the region.

Of course it would be impossible to have such a camp in connection with all logging operations. In the camp referred to the company has a 15-year supply of timber within a 15-minute ride on the logging road from the camp. The camp runs steadily, only shutting down for a few days at the Fourth of July and a week or so at Christmas.

WORKMEN'S COMPENSATION ACTS.

Until recently the responsibility of compensating injured laborers was regulated by employers' liability laws. These held the employer liable for accidents when he did not conform to the law. The employers protected their interests through liability insurance companies. This arrangement proved unsatisfactory. Lawsuits were common and proved a cumbersome method for determining whether compensation was due an injured workman or his dependents. Liability insurance was seemingly too expensive. On the other hand, injured workmen expended large sums of money for attorney's fees.

In addition compensation through liability laws tended to create an antagonistic feeling between employer and employee.

About one-half the States have passed workmen's compensation acts which provide for the payment by the State of specified sums to workmen for injuries received in the course of their employment, without the necessity of expense or delay. Both Washington and Oregon have workmen's compensation acts. In Washington the provisions of the act are obligatory on both the employer and the employee, the employers being required to pay monthly to the State a percentage of their pay rolls, the rate varying according to the hazard of the various occupations. In Oregon the act is of the presumptive elective type. While employers have the right to elect not to become subject to the act, they automatically come under its provisions if they do not serve written notice of rejection on the State. Employees in Oregon are also required to pay 1 cent for each day or part of day employed, the employers being authorized to make the collections.

In Washington the maximum rates have proved higher than was necessary, making it unnecessary for the operators to contribute toward the fund each month. The basic and assessed rates for the different departments of the logging operation for 1912, 1913, and 1914 were as follows:

TABLE 3.—*Rates of the Washington workmen's compensation act.*

Class of work.	Basic rate.	Assessed rate.						Average net equivalent rate for 1912, 1913, and 1914.
		1912		1913		1914		
		Months called.	Net equivalent rate.	Months called.	Net equivalent rate.	Months called.	Net equivalent rate.	
	Per cent.		*Per cent.*		*Per cent.*		*Per cent.*	*Per cent.*
Railroad construction	5	6	2.5	4	1.67	10	4.16	2.78
Railroad operation	5	6	2.5	4	1.67	10	4.16	2.78
Railroad maintenance	5	6	2.5	4	1.67	10	4.16	2.78
Logging proper	2.5	8	1.67	11	2.29	8	1.667	1.875

In Oregon the basic rates for the classes of work performed in logging are:

	Per cent.
Railroad construction	5
Railroad operation	5
Railroad maintenance	5
Logging proper	3½

The Oregon act makes provision for the assessment of lower rates. Where the accidents in the case of a given employer during the first year he is operating under the act do not require the State to pay out an amount in excess of 50 per cent of the employer's payments during that period, the employer's rate during the second year is reduced by 10 per cent. With a like experience during the second year the rate for the following year is reduced by a similar amount. This act resembles that of Washington in that employees are exempt from assessments whenever the surplus in the fund has assumed certain proportions. The act has been in force for such a short period that it is not possible to state what it will cost the employers on the average.

TAXATION.

The general property tax system is in vogue in Oregon and Washington, and, with few exceptions, all property, both real and personal, is taxed for State and local purposes. The levy varies considerably by districts in a given year, and in a given district from year to year, ranging from 20 to 30 mills in the suburban districts where logging operations are located.

The tax on logging operations, exclusive of their standing timber, amounts to from 3 to 5 cents per thousand feet of output.

SCALING AND GRADING.

In Oregon and Washington the Scribner and Spaulding log rules are in general use, the former being the preferred rule in Washington, the latter being almost universally used in Oregon. The Scribner rule is used by the Puget Sound Log Scaling and Grading Bureau, the Spaulding rule is the standard rule of the Columbia River Log Scaling and Grading Bureau. The Forest Service in national forest timber sales uses the Scribner Decimal C rule, which is a slight modification of the old Scribner rule.

In Oregon and Washington logs are always measured at the small end inside the bark, unless some other arrangement is agreed to by both parties to the sale. Logs are usually cut from 2 to 9 inches longer than standard lengths of boards, to allow for waste in handling and manufacture. This additional length is disregarded in scaling.

Log rules give the number of board feet in logs which are straight and sound. If logs are unsound, or otherwise defective, a certain allowance must be made by the scaler and the determination of the amount in board feet requires great skill.

FOREST SERVICE SCALING.

In a general way, Forest Service scaling practice is the same as that of the log scaling and grading bureaus and independent scalers of the region. It differs, however, in some particulars, which should be thoroughly understood by applicants for national forest timber; for the scale resulting from Forest Service practice, as a rule, is larger than that resulting from commercial scaling.

Briefly, scaling, as practiced by the Forest Service, is the measurement of sound material in the log and relates to quantity rather than quality. National forest timber, therefore, is scaled in accordance with the defect in the log and not in relation to any particular grade of lumber it will produce. On the national forests in Alaska and west of the summit of the Cascade Mountains in Oregon and Washington, logs up to and including 32 feet in length are scaled as one log; lengths from 34 to 64, inclusive, are scaled as two logs as nearly equal in length as possible in even feet, and increasing the diameter of the second log according to the taper of the first. Greater lengths than 64 feet are scaled as three logs, making the division as nearly equal as possible in even feet.

Timber sale contracts specify a definite overlength for trimming. This allowance is adapted to different logging conditions and to large and small timber. Three inches overlength may prove sufficient in small timber where danger from brooming is slight, while 9 inches or more may be reasonable in sales of large timber or where the danger of brooming in driving or chuting is great.

All diameters are measured inside the bark at the top end of the log, being rounded off to the nearest inch above or below the actual diameter. Logs which have a diameter exactly halfway between inches are thrown to the next lower inch. If logs are not round, they are scaled on the average diameter. Several diameters may be measured where necessary to obtain a fair average.

The Forest Service has formulated a number of rules for making discounts for defects, realizing that the effect of rot and other defects upon logs of different species and in different regions varies so greatly that no rule for making deductions can be applied inflexibly, and that the constant exercise of good judgment by scalers, based upon an accurate knowledge of local timber secured by seeing defective logs opened up under the saw, is essential.

Every timber-sale contract defines exactly the material to be classed as merchantable under its terms.

The methods of manufacture of particular purchasers are not taken into account by scalers. No attempt is made to adjust the scale to losses due to poor equipment or inefficient methods, to match up gains from exceptionally close utilization, or so modify the scale as to eliminate losses resulting from selling the log product on a different scale. The function of a Forest Service scaler is to determine the amount of sound material in the log as uniformly as possible, whatever the mill tally or the selling scale may be. The Forest Service gives no assurance or promises on the amount of the overrun. Systematic checks on the local scale are made by more experienced scalers of special competence. In case of a serious complaint the Service makes special check scales by the best men in its organization.

LOG SCALE THE BASIS IN LOGGING COST CALCULATIONS.

Loggers and lumber manufacturers uniformly think of logging costs in connection with the 1,000-foot unit. Loggers invariably prorate the logging costs on the basis of the log scale. Lumber manufacturers do not adhere to a uniform practice, sometimes prorating the logging costs on the mill tally, sometimes on both the mill tally and log scale. These two standards seldom agree, and it is necessary in a given case to know what standard has been used if one would avoid confusion. The product of the mill ordinarily overruns the log scale from 4 to 30 per cent, depending on the size, taper, and soundness of the timber, the thickness of the saws and other matters of mill equipment, the exact dimensions to which lumber is sawed, the class of material manufactured, and the loss in finishing and seasoning.

In this bulletin logging costs are uniformly based on the 1,000-foot log-scale unit unless an exception is noted. Logging-cost statements are based on the selling scale and not on a camp or Forest Service scale.

COST.

The bulk of the logs sold in the log markets of the Columbia River and Puget Sound regions are scaled by two log scaling and grading bureaus, corporations owned by independent loggers. In the Grays Harbor and Willapa Harbor regions scaling is done by independent scalers and costs about 5 cents per thousand feet.

Most logging operators who keep detailed cost accounts find it necessary to employ a camp scaler. A camp scaler is necessary in connection with practically all forms of bonus systems. Some camps get along without a camp scaler, keeping track of the output of the camp or the several units of production through a log or car count. A camp scale is not ordinarily considered as accurate as a selling scale. The camp scalers are paid from $75 to $125 per month.

Scaling in national forest timber sales is done by men regularly employed and paid by the Forest Service, which makes it possible for purchasers of national forest timber to get along without camp scalers. Purchasers who sell in the log markets, however, have to pay for a selling scale, as the Forest Service scale is not accepted by lumber manufacturers.

GRADING RULES.

As a general thing logs are sold by grades and species, so that it is desirable in most cases to sort the logs in rafting, each raft being made up of logs of one grade or species. The grading rules used by the Columbia River Log Scaling and Grading Bureau are as follows:

No. 1 logs.

No. 1 logs shall be 30 inches or over in diameter inside the bark at the small end, reasonably straight grained, and not less than 16 feet long, and shall be logs which, in the judgment of the scaler, will contain at least 50 per cent of their scaled contents in lumber in the grades of No. 1 and 2 clear.

In a general way a pitch ring is not a serious grade defect in a No. 1 log, provided its location and size do not prevent the logs cutting the required amount of clears. The same applies to rot.

Pitch pockets, seams, knots, etc., are defects which impair the grades in proportion to their effect on the amount of clears the log contains. A No. 1 log will admit of a few small knots, but must be surface clear for at least four-fifths of its length; a few pitch pockets, as permitted in the grade of clear lumber, but no combination of defects which will prevent the required percentage of clears.

No. 2 logs.

No. 2 logs shall be 16 inches or over in diameter inside the bark at the small end, not less than 16 feet long, and having defects which prevent its grading No. 1, but which will, in the judgment of the scaler, be suitable for the manufacture of lumber principally in grades of merchantable and better.

No. 3 logs.

No. 3 logs shall be 12 inches or over in diameter inside the bark at the small end, not less than 16 feet long, having defects which prevent its grading No. 2, and, in the judgment of the scaler, be suitable for the manufacture of the inferior grades of lumber.

Cull logs.

Cull logs shall be any logs which do not contain 50 per cent of sound lumber. All logs to be scaled by the Spaulding Rule.

The grading rules used by the Puget Sound Log Scaling and Grading Bureau are as follows:

No. 1 logs.

No. 1 logs shall be logs in the lengths of 16 to 32 feet and 30 inches inside the bark at the small end, and logs 34 to 40 feet and 28 inches in diameter at the small end, and shall be logs that, in the judgment of the scaler, contain at least 50 per cent of their scaled contents in lumber in the grades of No. 2 clear and better.

No. 2 logs.

No. 2 logs shall not be less than 16 feet long and having defects which prevent their grading No. 1, but which, in the judgment of the scaler, will be suitable for the manufacture of lumber principally in the grades of merchantable and better.

No. 3 logs.

No. 3 logs shall not be less than 16 feet long and having defects which prevent their grading No. 2, but which, in the judgment of the scaler, will be suitable for the manufacture of common lumber.

Cull logs.

Cull logs shall be any logs which, in the judgment of the scaler, will not cut 33⅓ per cent of sound lumber.

Rules for the grading of cedar, Douglas fir, spruce, and hemlock logs or shingle bolts were put in force in British Columbia not very long ago by the Forest Branch. The rules follow:

GRADING RULES FOR CEDAR LOGS.

No. 1 logs.

Logs 12 feet and over in length, 20 inches and over in diameter, that will cut out 50 per cent or over of their scaled contents in clear lumber. In cases of split timber above diameters will not be considered.

No. 2 logs.

Logs 12 feet and over in length, 14 inches and over in diameter, that will cut out merchantable or better, but which will not cut out to grade No. 1. This grade will also admit of a good grade of shingle log.

No. 3 logs.

Rough logs that are only fit for a low grade of shingles, shiplap, or dimension timbers.

Culls.

Logs lower in grade than No. 3 will be classed culls.

GRADING RULES FOR DOUGLAS FIR.

Flooring logs.

Logs suitable for flooring, reasonably straight, not less than 20 feet long, not less than 30 inches in diameter, clear, free from such defects as would impair their value for clear lumber.

Merchantable logs.

Logs not less than 14 inches in diameter, sound, reasonably straight, free from rotten knots; the grain straight enough to insure strength.

Rough logs.

Logs having visible defects such as crooks, bad knots, or defects that would impair the value and lower the grade of lumber below merchantable.

Cull logs.

Logs which will not produce 50 per cent of their contents in salable lumber shall be classed as culls.

GRADING RULES FOR SPRUCE, PINE, AND HEMLOCK.

No. 1 logs.

Logs 12 feet or over in length, 30 inches in diameter and over, up to 32 feet long; 28 inches if over 32 feet long; reasonably straight, clear, free from such defects as would impair their value for clear lumber.

No. 2 logs.

Logs not less than 14 inches in diameter, sound, reasonably straight, free from rotten knots or bunch knots; the grain straight enough to insure strength.

No. 3 logs.

Logs having visible defects such as crooks, bad knots, or other defects that would lower the grade below merchantable or No. 2.

Culls.

Logs which will not cut 50 per cent of their contents in salable lumber shall be classed as culls.

GRADING RULES FOR SHINGLE BOLTS.

Bolts to be measured in the following manner: To be as closely piled as possible, 4 feet high, 8 feet long, and the average number of pieces taken in the piles; the quantity to be obtained by dividnig the number of pieces by the average contained in the piles. If piled loosely, sufficient allowance to be made to make up a cord of closely piled bolts.

No. 1 bolts.

(*a*) To be of first-class timber of an average of not more than 30 bolts to the cord, 52 to 54 inches in length, straight, well made, hearted, and barked.

(*b*) Seventy per cent of the bolts to be clear; balance to allow of two small knots in each bolt, 1 inch in diameter.

(*c*) To be free from rot, shakes, and knot holes and other defects.

No. 2 bolts.

(*a*) To be well made, hearted, and barked, and of an average of not more than 36 bolts to the cord, 52 to 54 inches in length.

(*b*) To be free from rot, shakes, and worm holes.

No. 3 bolts.

(*a*) To be hearted and barked, not more than 40 bolts to the cord, 52 to 54 inches in length.

(*b*) Twenty-five per cent to be clear; balance to allow any bolt which has two cuts, with one knot 2 inches in diameter in each cut.

(*c*) To be free from rot, shakes, and worm holes; any bolts not up to standard of the grades to be considered culls.

PLANS.

The planning of the operation has received more attention in the Douglas fir region than elsewhere, largely because of the character of the country and the logging methods. Some operators, however, still cling to old methods.

All operations in the region are cruised, and usually some form of report is made and a map of some character submitted. The reports are usually conservative, and in many cases the maps are little more than sketches showing the more striking features of the area. Many operators have found it desirable to check their cruises and prepare topographic maps, on which are shown the following: The holdings of the company; the distribution of the stand by species, quality, and quantity; the location of streams, ridges, roads, trails, and tentative camp sites; the location of main logging railroads; and the division of the area into logging units. As to the question of accuracy, operators are governed by the character of their country and the uses to which the map is to be put. Where the map is to be used for the location of railroads and the estimation of logging costs, the field work is done intensively. The practice is still followed, however, by some operators of allowing certain woods employees to carry very valuable information regarding the timberlands in their heads, instead of having it on paper in the office.

RECORDS.

Operators as a class have not regarded the preparation of records as of much value, except in the case of operating costs. There are few operators who keep carefully written records of the achievements of past years and study them to weed out weak points in their management and methods. The most that is done is to ponder over the general experience of the past and, in a rather unsystematic manner, attempt to increase the efficiency of the work. This is remarkable in view of the fact that the managers in many cases are stockholders, and that cost figures, in connection with written records, provide the only sound basis on which new methods and principles may be founded. It should be understood that all operators do not neglect this means of improving their methods. Some are following modern business methods in this respect and to their advantage.

ACCOUNTS.

At present (1916) there are differences in the accounting methods of loggers because of the peculiarities of individual operations and because of a lack of understanding of the principles underlying proper accounting. Differences in logging methods, in the items which enter into the cost-keeping statements, in the methods of handling depreciation and the like, make it impossible for operators, even in the same region, to discuss intelligently their costs of production, especially the details. As a result, a feeling has arisen within and without the industry that a profitable field of endeavor would be the investigation of the basic principles which underlie costs and cost keeping and the preparation of a uniform cost sheet. Few question that a standardized cost-keeping system is practicable and would be of lasting value to the logging industry.

DEPRECIATION.

Until recently many operators followed the unwise and dangerous practice of taking no account of depreciation. The method of handling this account is optional with the operators, no provision for depreciation being prescribed by law; but the passage of the Federal income tax law has made it desirable for all operators to write off on their books a certain amount.

Depreciation is the shrinkage in value of an asset that results from its use. Lessening of the value of assets may be due to ordinary wear and tear, to physical deterioration, to inadequacy for the current needs of an operation, or to the exhaustion of available timber. The amount of such deterioration is charged against the operating profits, and so can be considered as an amount paid out of the proceeds of the business. The best concrete illustration is a sinking fund withdrawn from the proceeds of the business at regular intervals, deposited in a special account, and used to pay off bonds as they become due. In National Forest stumpage appraisals depreciation is reckoned as if charged off and withdrawn from the business at the end of the year. It is a sum, prorated over every thousand feet of timber cut, which in the course of the operation pays back the reduction in value of the fixed investments.

The rate of depreciation varies widely with the nature of the investment. Improvements are stationary, and so can be used only where they are built. They include all buildings, wagon and pole roads, railroad grades, bridges, splash dams, etc. The rate of depreciation on each improvement depends primarily upon the amount of timber which it can properly be used to log. When all of the tributary timber is removed, the improvements have no residual value. Improvements located with reference to large supplies of timber, like logging railroads, may have a very long life. Their rate of depreciation is correspondingly low. Equipment can be moved from place to place; so its depreciation depends primarily upon wear and tear, or the length of the ordinary working life. It includes tools, steam logging machinery, cables, railroad steel, rolling stock, etc. The working life given to different equipment in this publication is intended to represent current industrial experience in the region.

In times past some logging operators wrote off an arbitrary amount for depreciation. This was done to equalize profits, a large amount being charged off at the end of a prosperous year. Most operators charge off annually a certain percentage of the original cost, the amount being determined from an estimate of the life of the equipment. For example, a logging engine with an estimated life of eight years and no value at the end of that time is reckoned as depreciating 12½ per cent of its first cost each year. This method is used in making national forest timber appraisals.

AVERAGE TOTAL LOGGING COSTS.

The cost of logging in the region varies greatly; in 1913 it ranged from $4 to $7.50 per thousand feet. An average logging cost figure for a large region is rather indeterminate. In a given case the cost of logging may be lowest the first year or as soon as the business hits its stride, and increase gradually from year to year, the books showing the highest cost the last year, when the operator is cleaning up. This is due for the most part to the way the area is opened up, the operator pursuing the logical method of logging first the more accessible areas, which, as a rule, constitute the best logging chances. Methods of accounting can be devised which will tend to equalize the annual profits; but they can not change the fixed conditions which cause the actual cost of logging to be lower during the early life of the operation. The conclusion to be drawn is that an operator does not know what his average logging cost is until the last log has been hauled. Such being the case in a given operation, any statement purporting to represent the average logging cost for a region, even though it is based on sufficient accurate data and correct mathematical principles, is nothing more than a close approximation.

Table 4 gives the average cost per thousand feet log scale for delivering logs from the tree to the cargo mills of Puget Sound, the Columbia River, Grays Harbor, and Willapa Harbor in 1913. The average cost for the Puget Sound region is based on the output of 20 large camps, or about 900,000,000 feet, this output representing 75 per cent of the total output of the camps that dump into the Sound. The average cost for the Columbia River region is based on an output of 10 large camps, or about 385,000,000 feet. In the case of Gray's Harbor and Willapa Harbor regions the average cost is based on a smaller output, which makes the chance for error greater.

While it is reasonable to suppose that the average cost of logging in these four regions is approximately the same, too much stress should not be laid on the fact that this statement shows such to be the case. These costs are based on the selling log scale, and lack of standardization in scaling methods would indicate that this unit of measure varies somewhat by regions. Furthermore, the outputs on which these figures are based, with the exception of the Puget Sound region, are not large enough to give nicely accurate results. This is particularly true of the Grays Harbor and Willapa Harbor regions.

The statement does not include the cost of stumpage, interest of any kind, discounts on logs sold, or taxes on the standing timber. It includes only the cost of transforming and sorting the logs and taking them to the point at which they are manufactured into lumber. The manufacturers, as a rule, pay the cost of towing in the Puget Sound and Columbia River regions; in the Grays Harbor and Willapa Harbor regions the logger usually pays it.

The classification of costs given in the statement is not ideal. It is in fact an expedient. Operators use different classifications. In collecting the data the classifications of operators were followed, and later the classified costs were distributed in the best possible manner.

TABLE 4.—*Average cost per thousand feet in 1913 for delivering logs from the tree to the cargo mills of the Puget Sound, Columbia River, Grays Harbor, and Willapa Bay regions.*

Item.	Region.			
	Puget Sound.	Columbia River.	Grays Harbor.	Willapa Harbor.
1. Felling and bucking (labor)	$0.683	$0.70	$0.62	$0.62
2. Woods to car (labor)	1.259	1.31	1.81	1.81
3. Railroad (spur) and pole road construction (labor)	.586	.46	.50	.64
4. Train crews (labor)	.206	.24	.14	.09
5. Dumping and rafting (includes contract work) (labor)	.211	.16	.24	.20
6. Supplies and maintenance (labor and material) of railroad, dump, and boom	.177	.25	.14	.06
7. Supplies and maintenance (labor and material) of equipment, tools, buildings, etc	.307	.45	.32	.32
8. Fuel for locomotives, logging engines, shops, etc	.239	.23	.16	.14
9. Wire rope	.137	.15	.19	.20
10. Depreciation, equipment	.24	.28	.30	.30
11. Depreciation, main line railroad grade, boom, and buildings.	.066	.17	.07	.06
12. Scaling	.049	.05	.05	.05
13. Return of boom sticks	.046	.07		
14. Log freight	.882	.43	.59	.75
15. Salaries and commissions	.139	.14	.15	.15
16. Taxes	.029	.05	.035	.035
17. Industrial insurance	.096	.11	.08	.08
18. Sundry expenses	.076	.05	.10	.10
19. Driving			.14	.10
	5.428	5.30	5.635	5.705
20. Towing	.35	.50	.12	.080
Total	5.778	5.80	5.755	5.785

Item 2 includes the labor cost of yarding, swinging, roading, landing construction, and loading. The average cost of this work in any one of the four regions is higher than its average cost in camps that yard the logs direct to the track. The higher cost in the Grays Harbor and Willapa Harbor regions is due to the fact that a larger percentage of the timber is roaded relatively long distances to the railroads and drivable streams.

Item 3 includes the labor cost of spur railroad and pole road construction. Practically no pole roads are used in the Puget Sound and Columbia River regions, while in the Grays Harbor and Willapa Harbor regions they are necessary in many cases. The figures indicate that the cost per thousand feet for pole road construction may run as high as for railroad construction.

Item 4 includes the labor cost of train crews. Common carrier railroads are used more in the Puget Sound region than in the Columbia River region, which explains the lower cost in the former case. The loggers in the Grays Harbor and Willapa Harbor regions do not use the railroad so extensively as the loggers in the Puget Sound and Columbia River regions, the two former relying more on roading and river driving, which explains the lower cost

Item 5 is an average of the labor cost at those camps which do this work by day labor, also those that do it by contract; the contract rates in some cases only include labor, in others the total cost of the work. The cost in the Puget Sound, Grays Harbor, and Willapa Harbor regions includes more contract work than in the Columbia River region, which explains the lower cost in the latter case.

Item 6 includes the cost of supplies and maintenance (labor and material) of the railroad, dump, and boom. The cost is highest in the Columbia River region. This is because railroads owned by operators are longer in this region than in the other three. Also less contract dumping, sorting, and rafting is done there. The next higher cost is found in the Puget Sound region. This is largely because the loggers operate railroads much more extensively in this region than in the Grays Harbor and Willapa Harbor regions.

Items 7, 8, 9, and 14. Reasons for seeming discrepancies are brought out in the notes on items 2, 3, 4, 5, and 6.

Item 15 includes the salaries of superintendents or managers, bookkeepers, etc., at the main office, which is detached from the woods; also fixed sums paid to individuals or companies for selling the logs. The cost of camp foremen, bookkeepers, timekeepers, scalers, etc., is prorated against the major steps in the logging operation proper.

The camps of the Puget Sound and Columbia River regions group by total logging costs as follows:

PUGET SOUND REGION.

Cost per thousand feet.[1]	Number of camps.	Total yearly output of camps included in statement.
		Feet.
$4.00 to $4.50	4	177,000,000
$4.51 to $5.00	2	100,000,000
$5.01 to $5.50	5	220,000,000
$5.51 to $6.00	3	180,000,000
$6.01 to $7.00	3	135,000,000
$7.01 to $7.50	3	84,000,000
Total	20	896,000,000

[1] Does not include towing.

COLUMBIA RIVER REGION.

		Feet.
$4.00 to $4.50	2	90,000,000
$4.51 to $5.00	2	80,000,000
$5.01 to $5.50	3	80,000,000
$5.51 to $6.00	1	55,000,000
$6.01 to $7.00	2	80,000,000
Total	10	385,000,000

The average cost of logging in connection with 19 inland mills in Oregon and Washington, as worked out by Mr. Austin Cary[1] on the basis of the lumber produced and sold, amounted to $4.42 per thousand feet. The yearly output of the operations included in this statement ranged from seven to thirty-seven million feet. The difference between this average cost and the costs given in Table 4 can largely be explained on the ground that they are based on different units of measure; also by the fact that the average railroad haul is not so long in the case of the inland mills as of the cargo mills.

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[1] Logging engineer, Forest Service.

FIXED INVESTMENT.

The capital required for equipment and improvements varies greatly, depending for the most part on the output of the camp and the length of the railroad haul. In the case of going concerns, it depends on the age of the operation or the amount that has been written off for depreciation. For example, in the case of the 20 Puget Sound camps which have been referred to—camps of varying ages—the fixed investment at each camp ranged from $50,000 to $750,000; in the 10 Columbia River camps, from $75,000 to $750,000.

The following tabulation shows the approximate amounts invested for equipment and improvements in the 20 Puget Sound camps, together with their approximate daily output:

Fixed investment for camps.	Number of camps.	Approximate daily output (1913).
		Thousand feet.
$50,000 to $100,000	4	80 to 200
$100,001 to $150,000	8	150 to 350
$150,001 to $200,000	3	200 to 250
$200,001 to $300,000	2	200 to 250
$300,001 to $400,000	1	500
$400,000 to $500,000	1	150
$700,001 to $800,000	1	300

LOG PRICES.

From the log prices, shown in Table 5, which gives the prevailing prices paid for different grades of Douglas fir logs (the bulk of the output) for each month from January, 1909, to September, 1916, it is apparent that the prices fluctuate considerably, but that the spread between No. 1, No. 2, and No. 3 grades is practically uniform. The normal prices are $6, $9, and $12, and only when lumber prices are good do the log prices advance to $7, $10, and $13. The prices shown in the table are based on log scale and are considerably higher than the net cost per thousand feet of lumber produced, because of the surplus or overrun of the lumber tally over the log scale. In accordance with the usual practice of the region, the buyer may, at his option, take a 2 per cent discount by paying cash.

The prices of cedar, spruce, and hemlock logs are less susceptible of discussion; because, for the most part, they are not based to any extent on standard grades. The following log prices, taken from a trade journal, of March, 1917, will illustrate this and will give a general idea of log values:

> The stock of logs in the Columbia River district is not very heavy at this time, but ample for all demands. Present prices are: Yellow fir (large, old-growth Douglas fir), $6, $9, $12, with some sales at $5, $8, $11; camp-run, red fir (relatively small Douglas fir), $8.50; hemlock, $7; spruce, $12; cedar, $11.
>
> There is a normal supply of logs on Puget Sound. Prices for fir on grade, are $7, $10, and $13, respectively, with hemlock in demand at $7. Cedar is in good demand and is bringing from $10.50 to $12, according to quality. No spruce is being offered.

There is no surplus of logs on Grays Harbor. Prices on fir are $6, $9, and $12; hemlock, $6 to $7; spruce, $7 to $20.

Log prices in British Columbia are firm, with the supply very light. Fir is selling at $7, $10, and $13; hemlock, $7.50; cedar, $11.50 to $13; and spruce around $12.

TABLE 5.—*Prices of Douglas fir logs per thousand feet, by regions, 1909–1916.*

NO. 1 LOGS.

Year.	Region.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	Puget Sound	$13.00	$12.00	$12.00	$12.00	$12.00	$12.00	$12.00	$12.00	$12.00	$12.00	$12.00	$12.00
	Grays Harbor	12.50	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
	Columbia River	12.50	12.50	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
1910	Puget Sound	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
	Grays Harbor	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
	Columbia River	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
1911	Puget Sound	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	11.00	11.00
	Grays Harbor	13.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00
	Columbia River	13.00	13.00	13.00	13.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00
1912	Puget Sound	11.00	11.00	11.00	11.00	11.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00
	Grays Harbor	11.00	11.00	11.00	11.00	11.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00
	Columbia River	12.00	12.00	12.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00
1913	Puget Sound	13.00	13.00	13.50	13.50	14.00	14.00	14.00	14.00	13.00	12.00	12.00	12.00
	Grays Harbor	13.00	13.00	13.50	13.50	14.00	14.00	14.00	14.00	13.00	11.00	11.00	11.00
	Columbia River	13.00	13.00	13.50	13.50	14.00	14.00	14.00	13.00	11.00	11.00	11.50	11.50
1914	Puget Sound	12.00	12.00	12.00	12.00	11.00	11.00	11.00	12.00	11.50	11.00	11.00	11.00
	Grays Harbor	12.00	12.00	12.00	12.00	11.10	12.00	12.00	12.00	11.00	11.00	11.50	11.00
	Columbia River	12.00	12.00	12.00	12.00	11.10	11.00	11.00	11.00	11.00	11.00	11.50	11.50
1915	Puget Sound	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	Grays Harbor	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	Columbia River	11.50	11.00	11.50	11.50	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.50
1916	Puget Sound	12.00	12.00	13.00	13.00	13.00	13.00	13.00	12.00	......	......	......	......
	Grays Harbor	12.00	12.00	13.00	12.00	13.00	13.00	13.00	13.00	......	......	......	......
	Columbia River	13.00	13.00	12.00	13.00	13.00	12.00	12.00	12.00	......	......	......	......

NO. 2 LOGS.

Year.	Region.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	Puget Sound	$9.00	$9.00	$9.00	$9.00	$8.50	$8.00	$8.00	$9.00	$9.00	$9.00	$9.00	$9.00
	Grays Harbor	8.50	9.00	8.00	9.00	8.00	8.00	8.00	9.00	9.00	9.00	9.00	9.00
	Columbia River	8.50	8.50	8.00	9.00	8.00	8.00	8.00	9.00	9.00	9.00	9.00	9.00
1910	Puget Sound	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.50	10.00	10.00
	Grays Harbor	9.00	9.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
	Columbia River	9.00	9.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1911	Puget Sound	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
	Grays Harbor	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	8.50
	Columbia River	10.00	10.00	10.00	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	8.50
1912	Puget Sound	8.00	8.00	8.00	8.00	8.00	9.00	9.00	10.00	10.00	10.00	10.00	10.00
	Grays Harbor	8.00	8.00	8.00	8.00	8.00	9.00	9.00	10.00	10.00	10.00	10.00	10.00
	Columbia River	9.00	9.00	9.00	9.00	9.00	9.00	9.00	10.00	10.00	10.00	10.00	10.00
1913	Puget Sound	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	9.00	9.00
	Grays Harbor	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	9.00	9.00
	Columbia River	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	8.00	8.00	8.50	8.50
1914	Puget Sound	9.00	9.00	9.00	9.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Grays Harbor	9.00	9.00	9.00	9.00	8.00	9.00	8.00	8.00	8.00	8.00	8.50	8.00
	Columbia River	9.00	9.00	9.00	9.00	8.00	8.00	8.00	8.00	8.00	8.00	8.50	8.50
1915	Puget Sound	8.00	8.00	8.00	8.50	8.50	8.50	8.00	8.00	8.00	8.00	8.00	8.00
	Grays Harbor	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Columbia River	8.50	8.00	8.50	8.50	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.50
1916	Puget Sound	9.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	......	......	......	......
	Grays Harbor	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	......	......	......	......
	Columbia River	10.00	10.00	9.00	10.00	10.00	9.00	9.00	9.00	......	......	......	......

TABLE 5.—*Prices of Douglas fir logs per thousand feet, by regions, 1909–1916*—Continued.

NO. 3 LOGS.

Year.	Region.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	Puget Sound	$6.00	$6.00	$6.00	$6.00	$5.50	$5.50	$5.50	$5.50	$6.00	$6.00	$6.00	$6.00
	Grays Harbor	5.50	6.00	5.00	6.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00	6.00
	Columbia River	5.50	6.00	5.00	6.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00	6.00
1910	Puget Sound	6.50	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
	Grays Harbor	6.00	6.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
	Columbia River	6.00	6.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
1911	Puget Sound	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.50
	Grays Harbor	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.50
	Columbia River	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.50
1912	Puget Sound	5.50	5.50	5.50	5.50	5.50	6.00	6.00	6.00	7.00	7.00	7.00	7.00
	Grays Harbor	5.50	5.50	5.50	5.50	5.50	6.00	6.00	7.00	7.00	7.00	7.00	7.00
	Columbia River	6.00	6.00	6.00	6.00	6.00	6.00	6.00	7.00	7.00	7.00	7.00	7.00
1913	Puget Sound	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.00	6.00	6.00
	Grays Harbor	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00
	Columbia River	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	5.00	5.00	5.50	5.50
1914	Puget Sound	6.00	6.00	6.00	6.00	5.50	5.50	5.00	5.00	6.00	5.00	5.50	5.50
	Grays Harbor	6.00	6.00	6.00	6.00	5.50	6.00	5.00	5.00	5.00	5.00	5.50	5.00
	Columbia River	6.00	6.00	6.00	6.00	5.50	5.00	5.00	5.00	5.00	5.00	5.50	5.50
1915	Puget Sound	5.50	5.00	5.50	5.50	5.50	5.50	5.00	5.00	5.00	5.00	8.00	8.00
	Grays Harbor	5.00	5.00	5.50	6.00	5.00	5.00	5.00	5.00	5.00	6.00	8.00	8.00
	Columbia River	5.50	5.00	5.50	5.50	5.00	5.00	5.00	5.00	5.00	5.00	8.00	5.50
1916	Puget Sound	6.00	7.00	7.00	7.00	7.00	7.00	7.00	6.00	......	......	......	......
	Grays Harbor	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	......	......	......	......
	Columbia River	7.00	7.00	6.00	7.00	7.00	6.00	6.00	6.00	......	......	......	......

FELLING AND BUCKING.

ORGANIZATION OF CREWS.

Laying aside the question of direct supervision, undercutting, felling, and bucking are sometimes performed by three crews. An undercutter, or notcher, selects the trees to be felled, determines the direction they are to be thrown, and makes the undercut. Two fallers, sawing together as a second crew, then finish the second step in felling. The undercutter, or head bucker, next marks off the log lengths for the guidance of the buckers, who work singly with crosscut saws and cut the bole into lengths. As a rule, however, only two crews are used, the undercutting being done by the fallers. This is considered the best method.

In most of the large and better managed camps, a head bucker, working under the camp foreman, directs the work of felling and bucking, and marks off the log lengths. Occasionally in large timber and badly broken ground, the head bucker has an assistant to help mark off the log lengths, the resultant timber economies justifying the additional labor cost. In a few camps having a resident superintendent, the head bucker works under the superintendent rather than under the camp foreman, and only directs the work of the felling and bucking department, the marking of the log lengths being done by the buckers. A head bucker of the first class seldom has authority to hire his assistants, while one of the second generally has authority both to hire and to discharge. There are a number of rather large and efficiently managed camps in which the camp foreman has direct charge of the felling and bucking, the activity of the man, or the character of the logging operation as a whole, making it possible for him to keep a close check on the felling and bucking work, make assignments, specify the log lengths, and see that waste does not occur.

The head fallers and, generally, each bucker are held responsible to the head bucker or camp foreman for the quantity and quality of the work done. In a few cases, however, the buckers work in crews of three or four, and one of their number, besides doing the regular work of a bucker, acts as a strawboss, marks off the log lengths, and reports at stated periods the number of logs of different lengths cut. If the fallers and buckers are working under a bonus system, or if the management is keeping a close check on the amount of work done by each worker, a competent scaler is necessary.

METHODS.

THE DIRECTION OF FALL.

The first step in the felling of a tree is the selection of the direction in which it is to be thrown. This is governed by a number of factors, of which the following are the most important:

(1) The lean of the tree. By the use of wedges, a tree standing perpendicularly may be sawed to fall in any direction. A heavily leaning tree may be thrown by the same means in any one of three directions, namely, as it leans, or to either side. If the lean is not too great, the tree may be thrown in any one of four directions. However, with present standard equipment, that is, with the falling wedge (fig. 1), it costs too much to fell trees with other than a slight lean in a direction opposite to the lean, except to prevent excessive breakage and to avoid doing damage to improvements, equipment, etc.

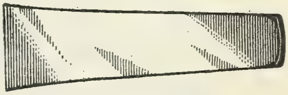

FIG. 1.—Falling wedge.

(2) The simplification of the first step in transportation. Timber cut for power yarding as a general thing should be thrown away from or toward the direction of haul, so that it can be moved with the least trouble, especially where the logs are cut into long lengths. Where short logs are cut, this is not essential.

(3) The protection of workers and timber. Trees which are felled up steep slopes are less likely to break because the distance of fall is less. As a rule, however, this method is not used, because it is costly and dangerous. On such ground the trees are thrown down or along the side of the hill. On slopes where the timber will lie

where felled, it is felled upgrade and, as in the case of level ground, into the green timber as far as practical. The aim at all times is to select a spot, or bed, where the bole of the tree will not be broken by the fall and will do no damage to other timber. It is occasionally necessary to make a bed for the large trees by swamping and leveling the ground, or by felling small, inferior species.

(4) The simplification of the work of cutting the trees into logs.

(5) The avoidance of lodging one tree in another.

THE UNDERCUT.

A wedge-shaped notch, or undercut, with a horizontal base in most cases, is cut in the trunk of the tree in the direction of fall, to guide the tree and to prevent the bole from splitting before it is completely severed from the stump. The depth of the undercut varies with the size and lean of the tree and the direction it is to be thrown, ranging from one-fifth to one-fourth of the diameter. It is deeper proportionately in small than in large timber. The undercut in trees that lean heavily in the felling direction is made deeper than usual in order to insure a clean break. For example, the undercut of a perpendicular tree 60 inches in diameter is about 15 inches deep; of a tree of the same size leaning 5 feet, about 24 inches deep; leaning 10 feet, about 30 inches deep. In trees that lean away from the felling direction and require heavy wedging, a smaller undercut is made in order to increase the power of the wedges. Under the latter condition the undercut may not be made until the felling cut is well in and the wedges started. The undercut is placed from 2 to 4 inches below the point at which the felling cut is to be started on the opposite side of the tree. The horizontal cut in most cases is made with a falling saw (fig. 2), the undercut being completed with a falling ax (fig. 3). In relatively small timber both faces of the undercut may be made with an ax. Not infrequently the height of the stumps cut makes the use of springboards (fig. 4), or some sort of scaffold, necessary when undercutting. Then, too, the fallers prefer to stand on springboards, even when the size of the roots does not make such a contrivance necessary. The ground around trees in the woods is more or less soft and does not give a firm foothold. If the ground is sloping, the tendency is for the

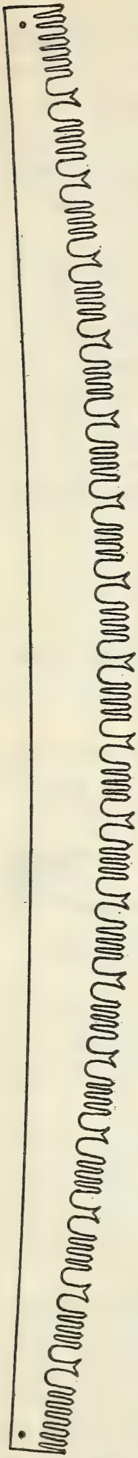

FIG. 2.—Falling saw.

feet of the fallers to slip downhill. The springboard, together with calked shoes, prevents this. Furthermore, there is a certain spring in the boards when the fallers are working that makes it easier for them to pull the saw.

THE FELLING CUT.

The undercut completed, the next step is the making of the felling cut. This is done with a falling saw. Prior to about 1880 the felling cut was made with an ax but not so satisfactory. Wedges can not be used when felling with an ax, so that it is difficult to throw a tree in any direction except that in which it leans. Furthermore, the output of a set of fallers is considerably less when working only with an ax than when working with saw and ax. Then, too, the loss of wood is larger when the ax is used exclusively.

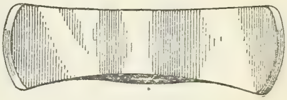

FIG. 3.—Falling ax.

The felling cut is started slightly above and opposite the undercut. When the saw has buried itself in the wood, steel wedges and plates are driven in behind it to prevent binding. In small, second-growth timber, the fallers may saw in a direction parallel to the undercut. As a rule, however, they change the direction of the cut so as to be continually sawing across a corner. If a tree leans heavily in the direction it is to be thrown, a different method is used. Such a tree will naturally break off while there is still considerable wood holding it to the stump; and, if any of this wood is on the outside of the tree, there is a likelihood of its splitting up the side of the butt log. To prevent this, the fallers make side cuts, so that there is nothing to break when the tree falls except the wood on the inside of the stump. Much the same method is used with a tree that is rotten about the heart.

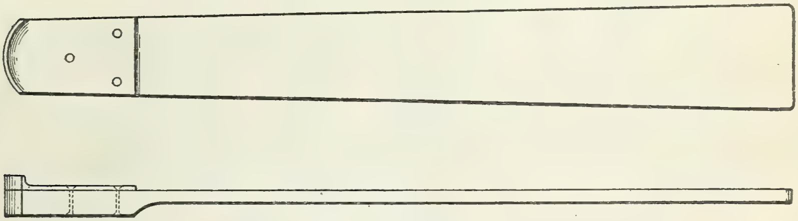

FIG. 4.—Spring or chopping board.

When it is desired to draw a tree slightly to one side of the direction in which it leans, the greatest thickness of wood between the felling cut and undercut is left on the side toward which it is desired to draw the tree. Wedges are also employed with this latter method.

Here, as in the case of undercutting, springboards are generally used.

BUCKING.

In bucking, the men work singly with bucking saws (fig. 5), the size of the trees and the way they lie making this, as a rule, the cheapest and most practical method. This crew cuts no limbs from the trees other than those that hinder the work of bucking. The limbing is left to a man called a swamper, knotter, or limber, who works with the initial transportation or yarding crew. A swamping ax (fig. 6) is used for this purpose.

In this region, where the timber is large and the ground steep and badly broken, bucking is difficult and dangerous work, requiring a high degree of skill.

The buckers are usually confronted with one of four situations, depending on the position of the felled tree:

(1) When the bole is lying flat on the ground, the bucker's work is simple, for after removing the bark, earth, etc., from the line of cut, he can easily saw through from the upper side, or if need be, from the lower. Before the saw begins to bind, bucking wedges (fig. 7) are driven into the kerf.

(2) When the bole is supported at both ends, the cut is started on the upper side and continued for about one-third of the distance through the log, or as far as the bind will permit. A cut is then started on the under side and continued until the log is severed. The bole, as a rule, is supported by heavy props placed under one or both sides of the cut. If the tree is not hung badly, the cut may be made from the upper side by using side wedges; that is, ordinary wedges driven in with the grain across the cut to prevent the log from rolling, binding, slabbing, or splitting.

(3) When the tree is supported at one end, care must be exercised to avoid splitting slabs from the under side. This is avoided by sawing on the under side of the bole until the saw starts to bind. In addition, the log, as a rule, has its free end supported by a heavy prop. The cut is continued, on the upper side, until the log breaks off from its own weight.

(4) When the bole is sprung between stumps, or side bound, it will spring back when sawed; and the general practice is to chop a deep kerf on the concave

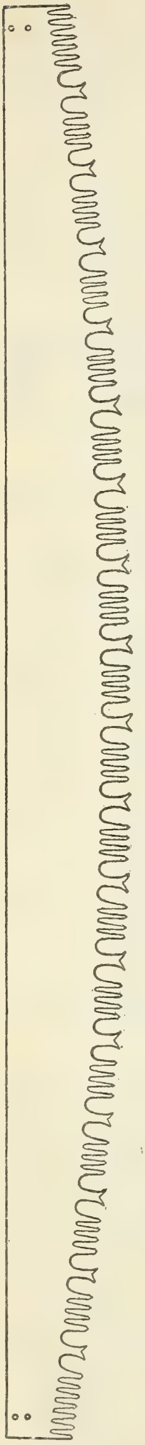
FIG. 5.—Bucking saw.

side and then to saw on a slant, taking as much wood as possible on the convex side.

STUMP HEIGHTS.

Frazier Curtis, writing on stump heights in 1900, implies that the height of stumps in this region at that time ranged from 3 to 5 feet, but that in times past it was customary to cut much higher stumps, some of them running as high as 20 feet. He speaks of one 160-acre tract where 2,000,000 feet of sound material had been left in high stumps.

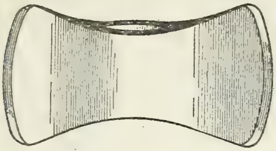

FIG. 6.—Swamping ax.

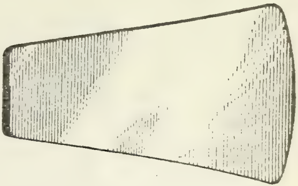

FIG. 7.—Bucking wedge.

The practice at the present time is to reduce the height of stumps to the lowest point practicable. The fact that most companies practice long butting rather than cut high stumps in questionable timber, which means an extra cut, indicates that they prefer to err on the side of labor rather than wood waste. Not all companies are so careful, since operations can be found where the stumps are higher than strict economy seems to require.

As to the average height of the stumps cut in this region, it is difficult to generalize. Taking it straight through, they probably range between 3 and 5 feet. Small, second-growth Douglas fir stumps are cut as low as 2 feet. Old hemlock stumps are frequently cut at seemingly wasteful heights, especially when the company does not follow the practice of long butting. It is not unusual to see old-growth cedar cut higher than 5 feet from the ground.

The stump heights on timber sales in the national forests of the region are a little lower than those in private cuttings of a like character. The clause relating to stump heights in a contract dealing with a recent sale of a body of timber in the Olympic National Forest reads:

> Stumps will be cut so as to cause the least possible waste, and not higher than 24 inches on the side adjacent to the highest ground, except in unusual cases, when, in the discretion of the forest officer in charge, this height is not considered practical.

LOG LENGTHS.

Douglas fir is well adapted to the manufacture of long timbers, and supplies a large share of the demand for such material. This has resulted in a type of mill designed to handle long logs economically. The methods of logging make it possible to handle relatively long logs more cheaply than short lengths, where the volume of such logs does not tax the equipment. The general tendency is to increase the length of the logs cut.

Logs, like lumber, are cut into even lengths, ranging from 16 to 60 feet and sometimes longer. The customary lengths range from 24 to 40 feet. Laying aside the factors of volume, grade, and utilization—woods and mill—logs as a rule should be cut about 40 feet in length, which is probably the most economical length to log and manufacture. Not infrequently the economical handling of timber of large diameter makes it necessary to cut some logs 24 feet in length. In cutting timber so that logs of the highest grade will result or so that the logs will contain the minimum amount of defective or broken material, it is necessary to vary the lengths, some of them running as short as 16 feet. On the other hand, logs up to 90 feet or more in length may be utilized in the manufacture of long timbers.

Logs longer than 40 feet bring special prices in the log market, because timber adapted for long logs of a certain grade is relatively less plentiful, and the seller may sacrific grade and scale in addition in some cases to the extra expense of logging them. One manufacturer on the Columbia River, when paying $9 per 1,000 feet for No. 2 Douglas fir logs of the usual lengths, paid the following prices per 1,000 feet by lengths for No. 2 Douglas fir logs 26 inches in diameter: Fifty to sixty feet, $11; 62 to 70 feet, $13; 72 to 80 feet, $15; 82 to 90 feet, $17.

It has been pointed out that it sometimes costs more to log long logs. For example, in one case a logging contractor was receiving in 1916 the following prices per 1,000 feet by lengths from a timber company for delivering logs from the stump to the raft: Forty-eight feet and under, $6.52; 48 to 60 feet, $7; 62 to 70 feet, $8.50; 72 to 80 feet, $9.50. The railroad haul from the landing to tidewater is 35 miles, the greater part of which is over a common-carrier railroad.

While some companies find it more expensive to handle logs 50, 60, 70, and 80 feet in length than logs of the usual lengths, largely because of the broken character of the ground they are operating in and the fact that the logs must be transported over a common-carrier railroad, some companies that own and operate all the railroad used in the transportation of their logs can handle long logs more economically than short ones (see "Ground Yarding Output"). These companies yard logs from 60 to 80 feet or more in length, or the entire bole of the tree to a top diameter of from 6 to 8 inches. The average length of the logs handled in a year by one company, operating in good ground and second-growth timber along the Columbia River, was 60 feet.

Long logs can be cut into shorter lengths at the landing, boom, or mill with a power machine more economically than in the woods with a crosscut saw, and special orders for unusal lengths can more readily be filled.

LONG BUTTING.

Some trees are defective at the base, the defect consisting of rot, shake, and pitchy material extending 6 feet or more up the tree. These defective ends will make little lumber, so little or no scale is given them. To include them with the butt logs would be poor economy, since it costs practically as much to log and saw defective as sound material, particularly in the case of operators who haul over a common-carrier railroad. This has resulted in the practice of bucking off that portion of the tree which in the judgment of the log marker is defective. The practice is known as long butting.

Old hemlock trees frequently need to be long butted, the defect at the base—rot, shakes, and checks—destroying the utility of the butt logs, though these defects are not so common or so injurious in western hemlock as in the eastern species. The operator can not afford to take any chances in the utilization of hemlock. Sound hemlock logs sold in 1916 from $5.50 to $6.50, in rare cases $7, per thousand feet, a price that about equals the price of the lowest grade of Douglas fir; so there is a comparatively small margin of profit, sometimes no margin. Then, too, if hemlock that has not been long butted is dumped into the water, driven, rafted, and towed some distance, or stays in the water any length of time, a portion of the butt logs will be lost through sinking or straying. The loss because of hemlock "sinkers" will vary. If no preventive measures are taken, such as long butting, cutting long-butt logs, "swinging" the butt logs in the raft, etc., the loss may amount to 10 or 15 per cent.

BREAKAGE.

With the felling of the first tree the logger was confronted with a problem of breakage, which was to remain to a great extent unsolved to the present and reach its most aggravated form on the Pacific coast.

No comprehensive study of breakage as it relates to this region has been made. Few companies have seen fit to study the losses that result. Different men have different ideas as to what the percentage is in the region as a whole or in a given camp. One head bucker puts the loss at 30 per cent of the timber felled, taking it straight through, 60 per cent of this loss being due to carelessness. Others estimate the breakage at from 5 to 15 per cent of the total merchantable stand.

The truth is, no one knows; no one has sufficient data on which to base a judgment. In some cases, because of the character of the ground and the size of the timber, the amount of breakage is so small that one may safely estimate it at 2 or 3 per cent; in others, where the slopes are rocky or broken up, it is so large that one feels justified in guessing it at 40 or 50 per cent. At one camp, where the timber is large and the ground is rough, in felling 1,000 thousand feet of timber, the breakage amounted to 9 per cent. At another camp the breakage on a 40-acre tract was 37 per cent. Taking it straight through the region, breakage probably runs from 10 to 15 per cent of the merchantable stand, being higher than this where the timber is large and defective or fire killed, or where the ground is particularly steep, rough, or rocky. Whatever the amount is, it will probably increase as operations are extended into the steeper places, unless different methods are used.

Waste resulting from breakage may be divided into three classes:

(1) That which can not be helped.

(2) That which is necessary to save more valuable timber.

(3) That which is preventable.

Just how much of the present breakage is preventable, no one is in a position to estimate confidently. Furthermore, it is not an easy matter to get at. Some men, however, think the amount in the aggregate is large.

It should not be inferred from anything that has been said that operators are not aware of this condition, and that they are not doing what they think should be done to reduce breakage to the minimum. Most of them aim to employ experienced head buckers and fallers; have the windfalls bucked ahead of the felling; have no timber felled across unbucked timber; have the fallers resort to wedging when it is necessary and practical; have two or three fellings made in dense stands when the logs are bucked in short lengths; have the larger and more valuable species felled first; have a bed made for the large timber when it is necessary and practical; and, when there is danger of a tree landing on a stump, have the stump bowled off on one side, or have poles laid against the stump, so that the tree landing on the stump will be sheered off and the force of the fall broken.

Fallers, however, often become careless, especially under a bonus system. Here, as in every other line of work, a check made occasionally is conducive to higher efficiency. A casual inspection, desirable as it may be, is not sufficient. An intensive inspection could be made by a head bucker and scaler working together to keep a check on the fallers and buckers and to collect data as a basis for comparing the breakage under different conditions.

The cost of unusual care may more than offset the gain resulting from reduced breakage. Generally speaking, there should be a relation between the loss through breakage and the value of the stumpage; loss through breakage should decrease as stumpage increases in value. In this connection it should be remembered that as a rule it is the top log or logs that are broken, and that these logs are relatively less valuable. On the other hand, breakage increases the cost of felling and bucking, also the cost of several other departments of the logging operation.

If it is true that operators who have purchased their timber outright not infrequently lose money through careless felling, it would seem that the Forest Service in basing the selling price of a block of timber on the amount logged and scaled should make sure that purchasers of National Forest timber exercise reasonable care in felling it. Forest Service timber sale contracts deal in a general way with the matter of felling, and on some features of the work state specifically what shall or shall not be done. Where the contract is not specific, the assumption is that the purchaser will do the work in accordance with the practice of progressive operators who are working in similar shows and own the timber.

WASTE IN BUCKING.

IMPROPER TRIMMING LENGTHS.

It is necessary to cut logs a few inches longer than the standard: (1) Because it is not possible for buckers to cut exactly at right angles, especially in large timber and on rough ground; (2) because logs are often damaged on the ends when being yarded, roaded, chuted, or driven, particularly in the last two methods of transportation; (3) to facilitate the work of the trimmer man at the mill, and to allow for the kerf cut by the trimmer saws. As a rule, the following allowances for trimming should be ample: Logs up to 32 feet in length, 5 inches; 32 to 48 feet, 7 inches; 48 feet and upward, 9 inches. In general, the allowance may be less in small than in large timber, less on good than on bad ground.

Workmen frequently become careless and cut the logs into improper lengths. This is due, for the most part, to the use of a measuring pole of the wrong length, the careless use of the pole, and the use in some places of a pole instead of a tape. Where less than 2 inches is left for trimming, 2 feet of log length may be lost at the mill; while on logs that are several inches too long, the loss is also considerable. Though no systematic study of this matter has been made, there are good reasons for thinking that the loss to the industry is worth considering. The measuring of 523 Douglas-fir logs at a mill on Puget Sound showed that only 139 logs were of the proper length, that 24 were too short, and that 360 were from 4 to 18 inches too long. The loss on these logs because of improper lengths is estimated at 13,230 feet, or 1.7 per cent of the scale. Assuming that the average value of the logs per thousand feet was $9, the total loss on the basis of 523 logs was $119, or $0.15 per thousand feet.

Employing an efficient head bucker undoubtedly results in a saving. Often a bucker has a measuring stick of the proper length, but, finding it takes more work to clear the brush away from a log or to do some extra wedging or undercutting, cuts the log longer or shorter than it should be. One of the most progressive operators of the region, finding that his company was sustaining considerable loss because of improper lengths, gave his head bucker an assistant, so that the log lengths could be marked off with a tape line. It was a very difficult bucking show.

DISREGARD OF QUALITY.

The buckers should exercise care in apportioning the boles of the trees, so that logs of the highest grade, or logs that will yield the largest amount of high-grade lumber with the minimum of trimming waste, will be obtained. It is no uncommon sight to see logs graded and sold as No. 2, or merchantable, which would have been graded as No. 1 logs had they been cut a few feet shorter. As No. 1 logs may be worth $12 per thousand feet when No. 2's are worth $9, it is clear that too much attention can not be given the matter of bucking for quality.

Proper supervision will help out greatly. Most buckers have good intentions, but are not well informed about log grades.

MISCELLANEOUS CAUSES.

Considerable waste not infrequently results from not utilizing as much of the tops as is practical. The bucking of crooked trees in the wrong place also results in waste, but in this region, where the trees are large, the amount is small. The same thing is true of the waste that results from cutting too far above or below the crotch of forked trees. Sawing too far below the break in broken timber may result in a small loss. The major portion of waste in bucking is probably due to inefficient or careless buckers. In large timber and rough ground failure to take out the bind of trees through a properly located initial cut, indifferent wedging, and carelessness in putting in props results in a comparatively heavy loss, logs not infrequently being slabbed or split for a considerable length. Splitting in hollow-butted cedar logs not infrequently results from cutting them too short or from not providing sufficient sound material to hold them intact.

OUTPUT.

An analysis of a number of felling and bucking cost statements indicates that the output of a set of fallers, as a general thing, ranges between 25,000 and 30,000 feet net scale per day. Some companies are averaging as high as 35,000 feet per day to a set of fallers; a few, 40,000 feet or more. Other companies are not averaging as much as 20,000 feet.

Two or three buckers are generally required with a set of fallers. It is not unusual to find three. If there are very few windfalls and the slope of the ground is fairly regular, so that little undercutting is necessary, two will be able to do the work. In good ground, where exceptionally long logs are cut, one bucker may be enough. The output of buckers ranges between 10,000 and 15,000 feet net scale per day, averaging about 12,000 feet. It would seem, judging from an analysis of cost statements, that the output in many cases is less than 10,000 feet. In one large camp, where the logs averaged about 36 feet in length and 1,800 feet in volume, and the ground was badly broken up, the average output per bucker per day over a period of 2 years was 9,500 feet.

TOOLS AND EQUIPMENT.

SAWS.

Two falling saws are required for each set of fallers, one for use while the other is being filed. The lengths range from 7½ to 10 feet, depending on the size of the timber. Eight feet is probably the most common length. Of course it is necessary in many cases to have a few 10 or 12 foot saws on hand for the larger trees. Two bucking saws are required for each bucker, their length varying with the size of the timber, 7½ feet being the common length. There must be some extra falling and bucking saws on hand, the number depending on the size of the operation.

The net prices in March, 1915, of a grade and pattern of falling and bucking saws used by a large number of Pacific coast logging operators were as follows:

Length of saw, feet.	Net price, each.
6	$5.00
6½	5.67
7	6.30
7½	7.00
8	7.60
8½	8.30
9	9.14
9½	9.96
10	10.77
11	12.60
12	14.49
14	18.46

These prices are a little high, which is due to present economic conditions. The falling saws are 13 gauge on teeth, 17 gauge on back; the bucking saws are 13 gauge on teeth, 18 gauge on back. Detachable wooden handles (fig. 8) are used. The reversible Pacific coast type costs about $0.65 per pair; the common type, $0.35 per pair.

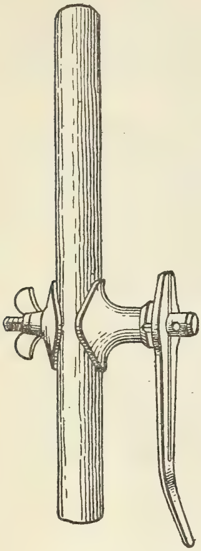

FIG. 8.—Saw handle.

AXES.

One falling ax is required for each faller; one swamping ax (fig. 6) for each bucker. The head of the axe used in the region is double-bitted; that is, has two cutting edges. Falling-ax heads vary in weight from 3½ to 4½ pounds; swamping-ax heads from 4 to 5 pounds, according to the character of work and the personal ideas of the workmen. The handles, which are made of straight-grained second-growth hickory, are straight and from 38 to 42 inches in length. The net price of the best quality of falling ax ranges from $11 to $12 per dozen; of the swamping ax, from $10 to $11 per dozen. The handles cost from $2.50 to $3.50 per dozen.

STEEL SLEDGES.

A steel sledge is used by each faller and bucker for driving wedges. The heads of those used by the fallers weigh about 10 pounds; those used by the buckers, 8 pounds. The cost of the heads ranges from $0.25 to $0.30 per pound; of the handles, from $2 to $2.50 per dozen.

STEEL WEDGES.

In well-equipped camps, each set of fallers has 4 or 5 steel falling wedges, and each bucker 4 or 5 bucking wedges, weighing from 6 to 8 pounds each. The cost of the best steel wedges is about $0.25 per pound.

SPRINGBOARDS.

In other than small second-growth timber and good ground each set of fallers is equipped with two spring, or chopping, boards which serve as platforms for them to stand on when undercutting and sawing. These boards are 4 or 5 feet long and 8 inches wide, tapering from 1 inch in thickness to 2 inches at the end, which is fitted with an iron spur. The springboard, with the spur uppermost, is thrust into a horizontally based notch cut into the tree. When the faller's weight is applied to the outer end of the board the spur is forced into the wood, preventing the board from slipping, keeping it level, and allowing it to be swung around with the iron spur serving as a hinge. The boards are made in the camps, generally by the blacksmith or filer, of maple or Douglas fir, generally the former. The irons or spurs (fig. 9), as a rule, are made by the camp blacksmith, although they may be purchased for about $1.25 per set.

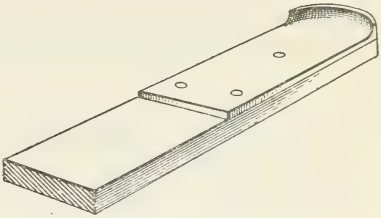
FIG. 9.—Chopping board iron.

UNDERCUTTERS.

It has been pointed out that in cutting trees into log lengths it is not infrequently necessary to put a cut in on the underside. To assist in holding the saw against the wood while undercutting is in progress, an undercutter may be used. There are several types on the market, one of which is shown in figure 10. The commonest practice is to insert the bit of an ax in the tree in such a way that the spring in the handle can be utilized to hold the saw to the cut.

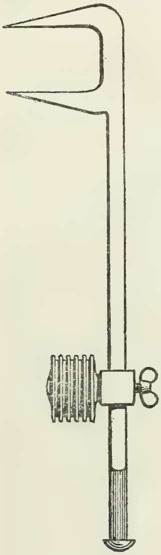
FIG. 10.—Undercutter.

SPECIAL EQUIPMENT.

TREE FALLER.

Among the recent innovations in logging equipment is the tree faller or jack. Its primary object is to enable timber fallers to throw trees in any direction regardless of the lean, thus making it possible to save considerable timber from breakage. Furthermore, if the machine is adapted to ordinary conditions, and the company manufacturing and selling it claims that it is, it will do way with wedging, which is a time and energy consuming operation.

As is shown in figures 11 and 12, the device embodies the simple principle of arms working on a fulcrum and spread through the agency of a slow-moving screw operated by a hand lever. It is made of special alloy steel, the required lifting power being enormous.

A roller thrust bearing reduces the friction. Separate oscillating plates are used to increase the compression surface. The opening between the jaws when the screw is fully extended is 7 inches.

The device complete, including the lever, weighs 166 pounds. However, it is of a take-down design, so that this weight can be divided about equally between the two fallers. Figure 13 shows the special pack boards used in carrying the parts in the woods. The amount of time consumed in taking down or assembling the machine is insignificant.

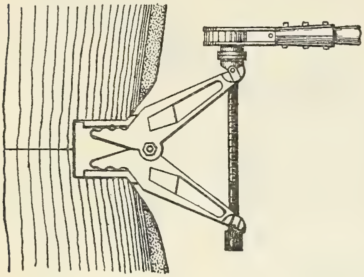

FIG. 11.—Method of inserting tree faller in notch.

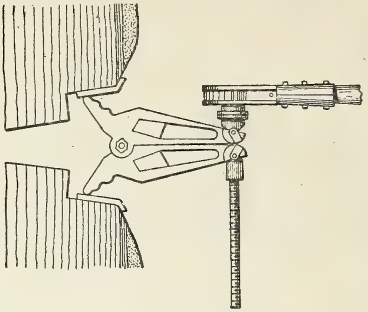

FIG. 12.—Cut opened about 7 inches with tree faller.

Figure 11 shows the method of inserting the jack in place on the oscillating plates, also the jack ready for operation, with the roller on the jaws nearest the fulcrum set in the third cavity of the plate. At this point of the operation the strain is greatest. Figure 12 shows the cut opened 7 inches with the end roller (the one farthest away from the fulcrum) set in the third roller cavity of the plate. At this point the strain is least.

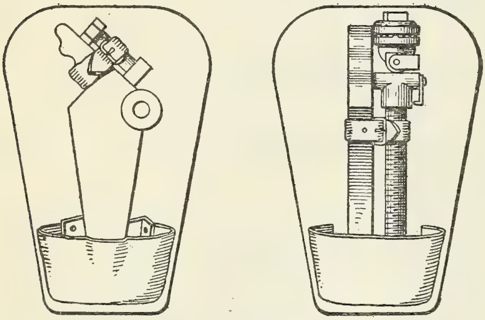

FIG. 13.—Method of carrying tree faller in the woods.

The manufacturers of this device have spent several years in experimental work, building several different types with several different kinds of steel. They now feel that the machine has passed the experimental stage. The principal difficulty has been in finding a steel that would stand the very trying service demanded of it. Jacks built of other steels than the kind now used stood the test for a while, and then broke under strains seemingly no more severe than those they had successfully withstood. It is to be hoped that the jack as now constructed will measure up to the expectations of the manufacturer; for, if it does, it will make a great saving in timber and human energy, also a reduction in logging costs.

The possibilities of the device were demonstrated before the members of the Pacific Logging Congress at Eureka, Cal. An 8-foot redwood, having an adverse lean of 5 feet, was thrown by the jack in a direction opposite to the lean in 13 minutes, notwithstanding the fact that 10 inches of "wood" was left uncut, and had to be broken by the power of the jack before the tree could fall. Other demonstrations have been made with equal success. One operator, working in a hard show, has used an earlier model for about 2 years with very satisfactory results. It is said that in a competitive test one set of fallers, aided by a jack, felled a 6½-foot tree having a lean of 6 feet in 3½ hours, while another set, working with wedges, required 13½ hours to fall a 5½-foot tree having a lean of 5 feet.

PORTABLE DRAG SAWS.

The portable drag saw is operated with either steam or gasoline, and is adapted for cutting saw logs, shingle bolts, cordwood, fuel for logging engines, etc. It can be operated by one man. A number of operators find its use profitable in bucking up fuel wood for logging engines. One machine may be used for two engines where they are located near one another. Where the ground is not too rough and the timber not too large, it may be used to advantage in bucking up trees into log lengths at the landings, especially where the timber is roaded to the landing.

Some think that the gasoline drag saw is not so well adapted for use by loggers as the steam saw, since it has not the capacity of the steam saw of the same weight and is more complicated in its make-up. However, improvement in gasoline drag saws has reduced the weight and increased the capacity so that they are now being universally installed, replacing cutting of fuel by man power. A gasoline saw is easily portable and can be taken anywhere by two men; it is not dependent upon a separate power plant and does not have to have the log moved to it for each cut. One man operates the saw and moves it to the log.

One steam saw has a 3¼-inch cylinder and a 30-inch stroke, running 225 strokes per minute. This machine is intended for use with a 6-horsepower vertical boiler and may be carried on a sled or low-wheel truck. The steam is conveyed in a ¾-inch pipe, joined in 8 or 10 foot lengths with flexible couplings. Steam may be conveyed successfully in this way for 300 feet. One hundred pounds steam pressure is ample for successful operation. Steam may also be taken from logging engines or other boilers through a similar system of piping. A hand rope gives the operator complete control of the saw when it is entering a log or when making the final light strokes in finishing a cut. When running at a normal speed the machine will cut a 30-inch log in 2 minutes, a 72-inch log in 14 minutes.

The price of this steam saw in 1916 was $200 f. o. b. Portland, including one 6-foot saw, but not the boiler. It weighs from 235 to 250 pounds. The shipping weight is 350 pounds.

One gasoline drag saw cut off logs in the water at the following rates:

Diameter of logs, inches.	Minutes.
50	11
51	13
54 (pitchy)	16
56	14
59	15
60	23

AVERAGE INVESTMENT IN EQUIPMENT AND SUPPLIES.

The investment in regular felling and bucking equipment, as shown by the inventory, at one operation cutting about 450,000 feet per day amounted to $1,442. This was the depreciated value of the equipment at the time the inventory was made, so that the first cost must have been considerably higher. Furthermore, the fallers filed their own saws, making it possible for the company to get along on less equipment than otherwise would be the case.

Table 6 gives the estimated average fixed investment in felling and bucking equipment and supplies at camps of different capacities. Freight is not included.

Table 6.—*Average investment in felling and bucking equipment and supplies.*

Item.	Capacity of camp per day.													
	50,000 feet.		75,000 feet.		100,000 feet.		125,000 feet.		150,000 feet.		175,000 feet.		200,000 feet.	
	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.
Falling saws and handles	7	$56.90	10	$77.85	13	$101.40	16	$124.95	18	$140.65	21	$164.20	23	$179.90
Bucking saws and handles	18	129.34	25	179.36	32	224.20	39	273.44	45	314.99	52	363.35	58	404.90
Falling axes and handles	7	10.00	10	13.90	13	16.80	16	21.70	18	24.30	21	28.20	23	30.80
Bucking axes and handles	10	13.60	14	14.80	18	24.00	22	25.70	25	33.10	29	38.30	32	42.20
Falling sledges and handles	6	20.40	8	26.90	10	33.60	12	40.20	13	43.50	15	50.10	16	43.40
Bucking sledges and handles	10	27.60	14	38.40	18	49.20	22	60.00	25	68.10	29	78.90	32	87.00
Falling wedges	15	30.00	21	42.00	27	44.00	34	68.00	39	78.00	45	90.00	50	100.00
Bucking wedges	32	56.00	46	80.50	60	105.00	74	129.50	86	150.50	100	175.00	102	196.00
Grindstones	1	6.00	2	12.00	2	12.00	3	18.00	3	18.00	4	24.00	4	74.00
Filing tools and equipment	...	20.00	...	20.00	...	20.00	...	20.00	...	30.00	....	30.00	....	30.00
Oil, files, etc	...	10.00	...	15.00	...	20.00	...	20.00	...	20.00	....	20.00	....	20.00
Total cost	...	379.84	...	520.71	...	650.20	...	801.49	...	921.14	....	1,062.05	....	1,208.20
Total weight (lbs.)	...	1,500	...	2,000	...	2,500	...	3,000	...	3,500	....	4,000	....	4,500

COST.

The cost of felling and bucking in the region ranges from $0.45 to $1 per thousand feet, averaging about $0.65. Cost data dealing with 40 large camps indicate that the average costs per thousand feet by districts are as follows:

Puget Sound	$0.68
Grays Harbor	.62
Willapa Harbor	.62
Columbia River	.70

FACTORS INFLUENCING THE COST.

Considering how much the cost of felling and bucking varies in different camps, to estimate it in a given case is no simple matter. Furthermore, it varies in the same camp at different times. At one camp it decreased steadily from $1.10 to $0.50 per thousand feet in five years, presumably because of increasing efficiency in the management; at another, it increased more or less steadily from $0.55 to $0.82 per thousand feet, largely because of the changing character of the show.

In a general way the following factors influence the cost of felling and bucking:

(1) Efficiency of labor and management.

(2) Scale of wages.

(3) Weather conditions. There is no doubt that the output of fallers and buckers varies with the weather and the length of the working day as fixed by light conditions. In timber appraisal not much weight need be given this factor. In collecting cost data and in making studies to arrive at standards to be used with bonus systems or systems for checking up the daily output of the workers considerable weight should be given it where the studies cover a relatively short period of time.

(4) The size of timber. It would seem, other factors being excluded, that the output of a set of fallers and buckers should, within certain limits, increase with the size of timber, both in height and diameter. Obviously, the output will be larger where the timber is relatively tall than where the opposite is the case. Then, too, the diameter seems to affect the output, fallers feeling that they secure the best results in timber that runs from 30 to 40 inches in diameter at breast height. If the factors of breakage and defect could be eliminated, they would probably do their best work in slightly larger timber.

(5) The percentage of breakage, the density of the stand, and the species of timber. Of these three factors, breakage is by far the most important. It is obvious that the output will be less where the percentage of breakage amounts to 40 per cent than where it amounts to

only 3 per cent. It would seem that the output should be less in light stands than dense ones, since more time is lost because of travel in a light stand than in a dense one, especially where the ground is steep and brushy. Of course, the opposite may be true when, because of the density or mixed character of the stand, two or more fellings are made. The difference in the output because of different species amounts to little or nothing, except as different species of the same diameter vary in volume, percentage of breakage, or percentage of defect. For example, the output of a set of fallers when working in western red cedar will be from 15 to 20 per cent less than when working in Douglas fir of the same diameter, because the volume of the trees will be less, breakage will be higher, and the percentage of merchantable timber will be less.

(6) The percentage of defect. Defect in timber increases the costs in the same way as breakage. This factor has been growing more important, and it will continue to grow in importance as utilization in the woods increases. Its effect in pushing up the cost is shown by the following case, which is exceptional: The fallers were paid (contract work) for 6,210,000 feet, gross scale; the buckers (contract work) for 4,773,000 feet, gross scale; while the logs hauled and utilized scaled 2,498,000 feet net scale.

(7) The length of the logs. As a rule, the output of bunkers is larger when long lengths are cut.

(8) The amount of windfalls. It has been pointed out that in order to keep the percentage of breakage as small as possible, it is necessary to buck the windfalls before the timber is felled. As a general thing, the merchantable material obtained from this class of timber is small, hence the cost of bucking varies with the character and number of windfalls.

(9) The steepness and roughness of the ground. As the ground becomes steeper and rougher, the percentage of breakage, the time lost in traveling from one tree to another, and the hazards of the work, also the amount of wedging, undercutting, and propping, increase. All these tend to reduce the output.

(10) The amount of brush. At times the brush is so thick that the fallers have to swamp out a trail in going from one tree to the other.

(11) The distance of the work from the camp. Time consumed and energy expended in getting to and from the work have an effect on the output.

EMPLOYMENT AND PAYMENT OF LABOR.

The basis of employment and payment of labor in this region is generally a 10-hour day, with a charge for board. Head buckers are sometimes paid by the month.

The wages paid the different members of the felling and bucking crew vary. During certain years, or parts of years, wages are higher than in others. At a given time some camps pay 8 to 10 per cent more per man than others. Then in the same camp some of the men, because of special fitness, receive a larger compensation than the others. For these reasons it is difficult to state the average wages paid the different members of these crews during the past several years.

The following list is intended to approximate the wages—average, high, and low—paid the members of the felling and bucking crews by the logging companies in the region during the six years ending 1916:

Position.	Wages per day.		
	Average.	High.	Low.
Head bucker	$3.50	$3.75	$3.25
Head faller	3.50	3.75	3.25
Second faller	3.25	3.50	3.00
Bucker	3.25	3.50	3.00
Filer	3.75	4.00	3.50

The wages given in the column headed "Low" do not represent the lowest wages that have been paid. Camps that have paid the wages included in column headed "Average" paid the following wages in October, 1915:

	Per day
Head bucker	$3.00
Head faller	3.00
Second faller	2.75
Bucker	2.50
Filer	3.00

The scale of wages for head buckers and filers is less standard than for the other members of the crews, hence the wages listed for them are more or less deceptive. Then, too, head buckers are paid more now than they were two or three years ago, some of them now being paid $5 or more per day. A good head bucker can easily earn this amount. Filers are paid from $3.50 to $5.50 per day, depending on their ability, the character and amount of work, and whether they are working as head or second filers.

A small percentage of the operators do the felling and bucking by contract, payment being made on the basis of the thousand feet net or gross log scale. The contract may be let to one man who employs labor by the day to do the work, or directly to the workers. Contract felling and bucking has not been popular in this region, chiefly for the following reasons: (1) The character of the work varies so much that it is difficult for the contracting parties to get together on terms with sufficient security; (2) breakage of timber in felling and bucking is likely to increase; (3) disputes may arise because of the way and time logs are scaled; (4) it does not work well to have two crews in a camp under different heads, which may result in a disparity in the wages paid or the hours worked, and thus breed discontent; (5) there are phases of the work that the contractor may not look after so well as an employee of the company.

A few camps use bonus or profit-sharing systems in connection with the felling and bucking. Two systems are in use. One consists of setting output standards for the fallers and buckers, and allowing each faller and bucker who has been in the employ of the company a certain length of time a certain amount per thousand feet in addition to the regular wage for every thousand feet felled and bucked in excess of the standard in a certain length of time, generally a month. One company that uses this system in three large camps, feels that it is a success, since it has enabled them to reduce their felling and bucking costs materially and to secure a knowledge of what fallers and buckers can and should do. Another company used this system for three months and went back to the straight wage system. The results obtained in the way of increased output were not disappointing. The trouble was that the workmen paid too much attention to the quantity and not enough to the quality of the work.

The other bonus system consists of setting a labor cost per thousand feet, and allowing each faller and bucker who has been in the employ of the company a certain length of time—say, 60 days—a portion of the difference between the actual and standard labor cost per thousand feet, on the basis of the number of days each has worked. In other words, if the total wages paid give an actual average cost per thousand feet of $0.55 and the standard cost per thousand feet is $0.65, the difference is divided between the fallers and buckers on the basis of the number of days they have worked.

One of the objections to bonus systems is that they tend to increase breakage. It would seem, however, that with proper supervision this objectionable feature could be practically eliminated.

SUPPLIES AND REPLACEMENTS.

It is impossible to say with any degree of certainty how much it costs per thousand feet for supplies and the replacement of equipment. The amount, however, is small and few logging companies have deemed it advisable to classify their logging costs in such a manner as to make this information available. It is close to $0.03 per thousand feet. The writer has seen annual segregated cost statements that indicate it to be as low as $0.01 per thousand feet; others as high as $0.04 per thousand feet. To get a correct figure, one would have to keep a careful record for three or four years. By no other means would it be possible to brush out the errors that creep into inventories of used equipment. Even a figure secured in this way would not fit all conditions. The above figure is intended to take care of the oil used in connection with the operation of felling and bucking and the supplies used by the filer, as well as the saws, axes, sledges, wedges, etc., used by the fallers and buckers.

The following statement which gives the estimated cost of equipment and supplies worn out, lost, or consumed in connection with the work of one set of fallers and three buckers in a season, indicates the probable life of the different kinds of equipment used. The following assumptions were made: (1) That one set of fallers, working 25 days per month for a season of 8 months, will fell 5,000,000 feet of timber; (2) that three buckers will be necessary to buck 5,000,000 feet of timber in addition to the down timber in the same period.

Equipment and supplies used up in a season.

Item.	Cost.	
	Unit.	Total.
2 falling saws	$7.20	$14.40
4 bucking saws	6.60	26.40
5 saw handles	.65	3.25
2 falling axes	1.00	2.00
3 swamping axes	1.00	3.00
40 1-pound falling wedges	.25	10.00
60 1-pound bucking wedges	.25	15.00
1 10-pound falling sledge	3.00	3.00
3 8-pound bucking sledges	2.40	7.20
2 dozen axe and sledge handles	3.60	7.20
2 iron shoes (springboard)	.60	1.20
Oil and supplies		50.00
Total cost		142.65
Cost per thousand feet		.0284

FILING.

In times past, the fitting of the saws was done by the fallers and buckers. Now it is ordinarily done by filers who are regularly employed at this work. All camps employ one filer; the larger camps, two. If the operation is large and scattered, three filers are sometimes necessary. In a general way, one filer can do the work in a camp having an output of 150,000 feet per day or less; two are necessary if the output exceeds this figure.

The number of saws that a filer should sharpen in a day varies with the ability of the filer, the character of the chance, and the length of time the saws are used before they are filed. Taking it straight through, a filer sharpens from 10 to 12 saws per day. The number is frequently as high as 16 saws per day.

There is no rule governing the length of time a saw, falling or bucking, should be used before it is refitted. The time depends to a great extent on those using the saw, also the chance it is used in. Sometimes it is filed every day. Possibly both classes of saws are filed every one and one-half days on the average.

In addition to fitting the saws used by the regular fallers and buckers, the filer fits the saws used by the wood buckers employed with the yarding, loading, chunking-out, and scraper donkey crews.

COST OF SPECIFIC CASES.

The following gives the cost of felling and bucking at several camps. They are typical of most of the conditions in the region.

(1) Cost of felling and bucking on the west foothills of the Cascades in Oregon in 1911.

The topography was rather rough, both in major and in minor features. Slopes of from 30 to 70 per cent were not uncommon. Much of the area would be considered a fair chance.

The timber consisted of a heavy stand of very defective Douglas fir in mixture with a small percentage of hemlock and cedar. Out of a gross stand of 80,000 feet or more per acre only about 50,000 was hauled out. The logs averaged about 1,400 feet in volume.

For a long time the company allowed the foreman or fallers to decide, from their general appearance, what trees it would pay to fell. This resulted in a large proportion of the stands being left unfelled, the amount ranging from practically nothing on some acres to 30,000 feet or more on others. The leaving of so much timber seemed like waste to some of the members of the company, and cleaner cutting was tried. Some areas were cut over the second time, and the timber proved to be nearly as sound as that secured at the first cutting. The management now feels that it is impossible to determine which of the timber should be utilized without felling and bucking practically all of it, and this is the policy they are now following.

The cost per thousand feet in the year 1911, when practically everything was felled, was as follows:

Felling, labor	$0.437
Bucking, labor	.499
Supplies and equipment	.030
Total cost	.966

This cost is based on the mill scale, which was close to the lumber tally. It includes the wages of the filer, scaler, and marker. The fallers were paid from $0.15 to $0.17 per thousand feet for felling, the bucker from $0.15 to $0.21 per thousand feet for bucking, regardless of whether the logs were sound or not.

It cost about $0.25 more per thousand feet when practically everything was cut than it did when a large proportion of the stand was left as presumably worthless.

(2) The labor cost per thousand feet, selling scale, for felling and bucking at a camp on the flat to the west of the Cascades in Washington, based on a period of six months in 1912 and an output of 25,000,000 feet.

The ground was practically level and quite free of brush and down timber. Few hummocks, pot holes, or troublesome ravines were encountered.

While the timber was relatively small, the stand was dense, cutting out from 85,000 to 90,000 feet per acre. It averaged about 30 inches in diameter, breast high, and was of good height. The logs averaged 550 feet in volume and ranged from 32 to 40 feet in length. The timber was practically sound, the breakage amounting to not more than 5 per cent.

Five sets of fallers worked with the three sides, averaging about 28,000 feet per set per day. Approximately three buckers worked with a set of fallers, bucking both the down and felled timber.

The average cost per thousand feet for labor amounted to $0.49. One filer was employed. The camp foreman was directly in charge of the work, but none of his salary is included in this cost. The following daily wages were paid: Head fallers, $3.25 to $3.50; second fallers, $3 to $3.25; buckers, $3; filer, $3.75.

(3) Cost of felling and bucking at a camp along the Columbia River in Washington in the years 1910, 1911, 1912, and 1915.

The tract was mountainous, rough, and broken up, the slopes generally being quite steep. No rock outcrops or cliffs were encountered. There was a considerable amount of down timber and an average amount of brush.

The timber was large old-growth fir, which was cutting out from 80,000 to 100,000 feet to the acre, with about 20,000 feet of hemlock left. It was the policy of the management to cut no hemlock under 28 inches in diameter, breast high. Little fir, cedar, or spruce was left. Breakage amounted to 10 or 15 per cent. The logs averaged about 36 feet in length and 1,900 feet in volume.

The average labor cost per thousand feet in 1912, which was based on an output of 38,000,000 feet, was as follows:

Felling	$0.168
Bucking	.382
Total	.550

The felling cost includes the wages of the fallers and one-half the wages of the filer; the bucking cost includes the wages of the buckers, head bucker, assistant head bucker, and one-half the wages of the saw filer. The following daily wages were paid. Head fallers, $3,75;

second fallers, $3.40 to $3.50; head bucker, $3.75; assistant head bucker, $3; buckers, $3.25.

The labor cost per thousand feet in other years was as follows: 1911, felling $0.31, bucking $0.46; 1910, felling and bucking, $1.10; 1915, felling and bucking, $0.49. In 1915 the company used a bonus system in connection with the felling and bucking.

The head bucker supervised the felling and bucking work and, with an assistant, marked the log lengths. The logs were measured with a tape. Prior to the adoption of this method the management experienced great difficulty in getting the logs bucked square off and of the desired length.

During the year the company averaged about 3 sets of fallers and about 16 buckers per day. This is 5 buckers to a set of fallers, and seems high. However, we have noted that there was a considerable amount of down timber, and that the size of the timber and the character of the ground made it a difficult and dangerous bucking chance.

(4) Labor cost per thousand feet for felling and bucking at a camp along the Columbia River in Oregon in 1911 and 1912.

The area was quite level, the surface regular, being considered one of the best ground chances in this region.

It was a second-growth forest which was cutting out about 80,000 feet per acre, the trees averaging about 28 inches in diameter breast high. From 90 to 95 per cent of the stand was Douglas fir, the rest hemlock. The timber was practically sound, and breakage did not amount to 5 per cent. The logs averaged about 60 feet in length and 800 feet in volume.

The labor cost per thousand feet in 1911 was $0.295 for felling and $0.227 for bucking. The felling cost includes one-half the wages of the filer; the bucking cost, the wages of the head bucker and one-half the wages of the filer. Approximately two buckers worked with a set of fallers. The following daily wages were paid: Head fallers, $3.75; second fallers, $3.50; buckers, $3.25; head bucker, $3.75; filer, $3.50.

The labor cost per thousand feet in 1912 was $0.298 for felling and $0.308 for bucking.

(5) Labor cost per thousand feet for felling and bucking at a camp on the western foothills of the Cascades in Washington in 1911 and 1912.

The area covered during these two years was of mixed topography, there being good and bad chances. Some parts of the ground were quite level, with a relatively smooth surface; other parts, while quite level in general, were badly broken up by small hummocks and pot holes. Slopes of from 30 to 60 per cent were not uncommon, their surfaces varying in smoothness like the level land.

As to size, the timber could be classified as a mixture of old and second-growth stands. It was cutting out about 50,000 feet per acre, as follows: Douglas fir, 50 per cent; cedar, 45 per cent; hemlock, 5 per cent. The logs averaged about 36 feet in length and 1,000 feet in volume.

The labor cost per thousand feet was $0.717 for felling and bucking in 1912 and $0.644 for felling and bucking in 1911. The lower cost in 1911 was no doubt largely due to the fact that in this year the ground was more level and the percentage of cedar a little less.

In Table 7 are given the costs of felling and bucking at several camps in the region. For the most part they represent averages for a year or more.

TABLE 7.—*Costs of felling and bucking.*

Camp.	Cost per thousand feet.	Period.	Year.	General location of camp.
1	$0.60	6 months	1913	Washington, west slope of Cascade Mountains.
2	.71	1 year	1911	Do.
3	.58	do	1913	Do.
4	.69	do	1911	Do.
5	.41	do	1911	Do.
6	.67	do	1911	Do.
7	.67	do	1911	Do.
8	.68	do	1912	Do.
9	.89	2 years	1913–1914	Do.
10	.77	do	1913–1914	Do.
11	.80	1 year	1914	Do.
12	.80	do	1913	Do.
13	.75	do	1914	Washington, west foothills of Cascade Mountains.
14	.72	do	1912	Do.
15	.64	do	1911	Do.
16	.52	do	1914	Do.
17	.58	9 years	1905–1914	Do.
18	.98	1 year	1914	Do.
19	.64	5 years	1911–1914	Do.
20	.60	1 year	1913	Do.
21	.60	do	1914	Do.
22	.49	6 months	1912	Washington, Sound region.
23	.68	7 years	1907–1914	Do.
24	.69	3 years	1912–1914	Do.
25	.68	1 year	1913	Do.
26	.69	do	1914	Washington, slopes and foothills Olympic Mountains.
27	.70	do	1914	Do.
28	.65	6 years	1908–1914	Do. Do.
29	.68	1 year	1914	
30	.49	do	1915	Washington, along Columbia River.
	.55	do	1912	
	.77	do	1911	
	1.10	do	1910	
31	.81	do	1913	Do.
	.64	do	1912	
	.57	do	1911	
	.64	do	1910	
	.67	do	1909	
	.55	do	1908	
	.58	do	1907	
32	.72	do	1912	Do.
33	.72	5 months	1913	Oregon, along Columbia River.
34	.52	1 year	1912	Do.
35	.61	do	1911	Do.
36	.80	do	1912	Do.
37	.71	do	1911	Do.
38	.99	do	1912	Oregon, west slope Cascade Mountains.

PRIMARY LOG TRANSPORTATION.

TYPES OF POWER USED.

HANDWORK.

In the early history of the industry in the region hand logging was common. The timber was felled on slopes close to tidewater or some drivable stream, the logs were driven if need be, made into rafts, and towed to the mills. In British Columbia and Alaska hand logging is still practiced to a limited extent.

ANIMALS.

For many years animals constituted the only draft power used in logging in this region—first, oxen; later, horses. As long as the haul was short the ox was preferred, because it could live on coarse feed, draw heavier loads, stand rougher treatment, and required an inexpensive harness which could be made in camp. The ox does not mire so badly as the smaller-footed horse and is not excitable in difficult situations. When the hauls became long, the horse was used because it is more active than the ox. The ox, however, continued to divide the labor of transportation with the horse, the former being used to deliver the logs from the stump to the skid road, the latter to haul the logs without the use of a vehicle over the skid road to the mill, drivable stream, or railroad. Horses were introduced at about the same time as logging engines, and are still used to a very limited extent in second-growth timber. Extensive cutting will undoubtedly increase the use of horses.

The logs were first dragged out over trails, from which only such obstructions had been removed as were necessary to make the method feasible. So that it would not be necessary to move the logs over the ground for a distance greater than 300 feet, skid roads were brought close to the timber. This, however, was not practical at all times, and frequently logs were dragged over the ground for 1,000 feet or more on hand skids.

The second step was to drag the logs over skid roads, either with oxen or horses, for distances ranging up to a mile or more. The skid roads were carefully located, stumps were removed, cuts and fills made, and the roadbed leveled to give the best possible grade. Skids about 10 feet long and from 10 to 14 inches in diameter were laid across the completed grade at 10-foot intervals, and partly buried in the ground. A "saddle" was cut out of the center of each skid for the logs to ride in. On curves the outer ends were elevated slightly. On level stretches the saddles were greased to reduce friction. The logs were fastened together by means of grabs or dogs into long turns, each averaging about 1,000 feet board measure per horse. A team on a road of this character consisted of from 5 to 10 yoke of oxen or from 4 to 14 horses.

ENGINES.

The first patent on power skidding machinery in the United States was granted in 1883, and covered an overhead cableway system to get logs out of potholes and swampy places. It was tried out in the cypress forests of North Carolina, with the machines mounted on scows and floated in the bayous and sloughs. It did not completely solve the problem, since its range was limited to 700 or 800 feet. A ground yarding system was operated in a Louisiana swamp in 1889. It consisted of two large drums and an engine and boiler mounted on a scow, from which what in effect was an endless cable passed out into the forest for a distance of half a mile. This later developed into the system used on pull boats.

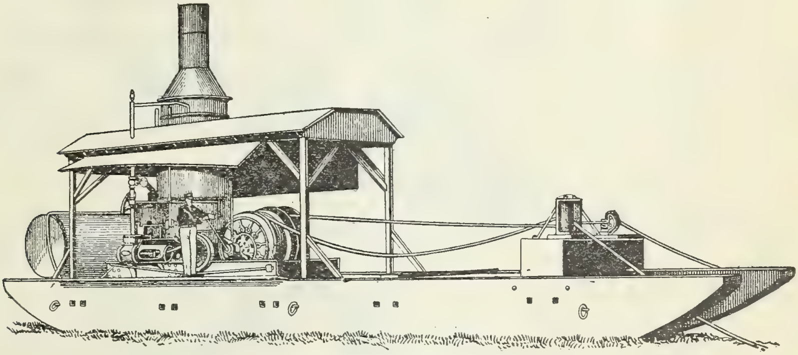

FIG. 14.—Yarding engine and sled.

Power yarding was first used in the Douglas fir forests of the Pacific coast in 1890, or one or two years before, in connection with a ground rope system. One vertical-windlass and one link-motion vertical engine, attached to an upright boiler was mounted on a sled, from which a single line was passed into the woods by horsepower. The spool was driven directly by a pinion and wheel, both of which were bevel cored. This system was first used in California about 1885.

Power yarding was superior to animal yarding from the beginning, and its popularity resulted in comparatively few horses or oxen being used in the Douglas fir region by 1900. The gradual evolution of logging engines has given the industry the compound-geared, ground-yarding engine and the long-range, high-speed roading engine, both of which seem to have reached perfection, also fairly satisfactory overhead and high-lead logging engines, which without doubt are susceptible of further improvement.

The present ground logging engine consists of an upright boiler, two horizontal engines, two main drums, and usually a third small drum, mounted on a steel frame, all of which, in turn, are mounted on a wooden sled. (Fig. 14.) The large drums may be placed tandem, one carrying the hauling line and the other the return line. The third drum carries the straw line, which is used to run out the return or trip line, either when a new setting is being made or when roads are being changed. The engines are classified as simple and compound geared. They are further classified as yarding, swinging, or roading engines. An engine having the gears compounded is always classed as a yarding engine. One of the simple geared type is known as a yarding, swinging, or roading engine. The roading engine has a larger drum capacity than the yarding or swinging engine. In effect, the swinging engine, an intermediate type, is a roading engine, except that it does not have such a large drum capacity.

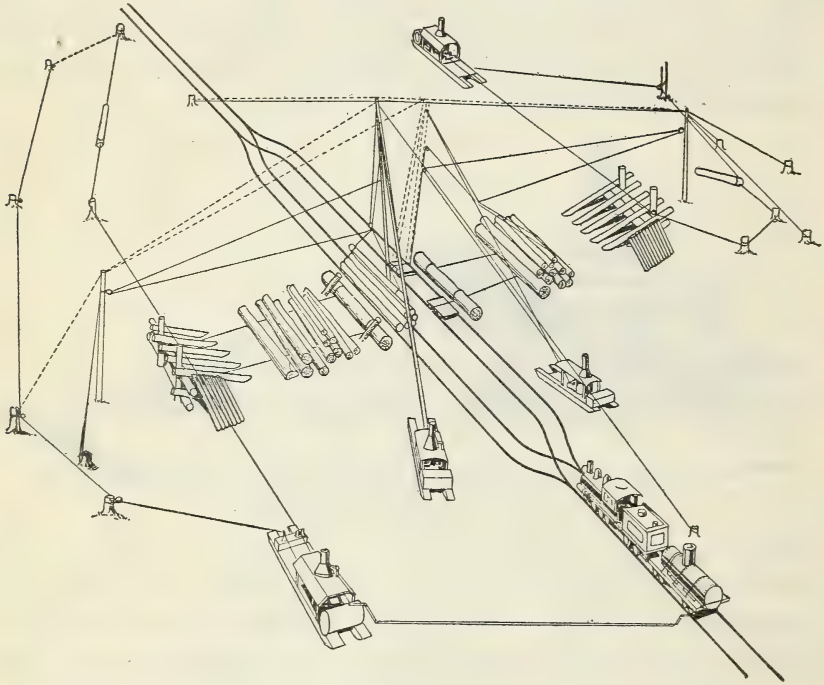

FIG. 15.—Location of improvements and equipment in ground logging.

The ground type of logging engine is brought to the site on a flat car and unloaded by means of cables and blocks, power for the latter step being furnished by the engine itself. High-lead and overhead engines, as a rule, are mounted on cars instead of sleds, and are transported from one setting to another by their own power or by a locomotive. Where railroads are not used in connection with the logging operation, or where the yarding engines are hauling in conjunction with roading or swinging engines, yarding engines are dragged over the ground by their own lines attached to stumps along the way.

The method of operation is dependent largely on the topography of the region. The more common practice in the case of ground logging is to build a landing at a suitable spot along a railroad and to install a yarding engine at one end of it. (Fig. 15.) When the area tributary to this location is logged, the yarding engine is shifted to the opposite end of the landing. In some cases a roading engine is installed at a landing or on the bank of a drivable stream from which a pole road extends into the timber. The timber is then transported to the pole road by a yarding engine in the same manner as in the case of a railroad. It may happen that a pole road is not advisable, in which event the logs are dragged over the ground from the yarder to the landing by a swinging engine. If it is not economical to single haul the logs from the yarder to the pole road, a swing engine is used to transport them over the ground. In times past the logs were hauled over the ground to a railroad, made into turns, and dragged over the ties to the mill or water by a locomotive. This latter, however, was an unusual method.

STEPS IN THE OPERATION.

The initial step in the transportation of a log from the stump to the mill is generally known on the Pacific coast as yarding. Skidding is a term that is coming into use to designate this operation, especially where certain overhead systems do the work. It consists of assembling the logs at common points for some other method of transportation. This common point in the case of power yarding is at the yarding engine, at a distance ranging from 500 to more than 2,500 feet from the farthermost tree that is to be yarded at that setting. The yarding engine is set at a drivable stream, railroad, pole road, chute, flume, or "swinging" road, depending on the next step in the transportation of the log. Yarding and the second step in transportation can go on simultaneously when the second step is not driving. Where driving follows yarding, conditions may be such that the second step is delayed.

The above seems to indicate that yarding consists of that transportation accomplished by but one logging engine, which, strictly speaking, is true. The term, however, is applied more broadly to the work done by two or more engines working tandem, provided no costly structure with considerable life, like a pole road, is employed. In that case the long haul over the prepared road is called "roading." The term "yarding" is frequently applied to the whole process—"single," "double," or "triple yarding" being more accurately descriptive terms; or the second and third hauls may be denominated "swinging." The terms are loosely used by the industry, however, so that for clear and accurate discussion, definition of terms is necessary, which in the very nature of the case must be more or less arbitrary.

The term "yarding" in this bulletin is confined to the first haul, which takes the log at the stump. Swinging is considered as transportation that delivers the log from the yarding engine to a pole road, chute, railroad, or drivable stream. One or more engines, of either ground or overhead type, may do the work, but always in connection with very temporary improvements. Roading is considered as the transportation of logs by a logging engine or engines in connection with improvements that are to some extent permanent in character, such improvements consisting of pole roads, chutes, overhead cables, etc.

YARDING.

METHODS.

Power yarding is done in three ways: First, with the log dragging on the ground and the haul-in or main yarding line leading along the surface of the ground from the yarding engine to the log; second, with the log dragging on the ground and the main yarding line leading from the yarding engine to a large lead block suspended near the top of a spar tree standing close by and thence out to the log; third, with the log riding suspended, or partly suspended, from an overhead cable. The first system is known as ground yarding; the second, as high-lead yarding; and the third, as overhead yarding. In addition to these three yarding systems, there are a great number of methods and a great variety of labor, equipment, and supplies used in yarding; more than in any other step in the logging operation.

FACTORS INFLUENCING THE OUTPUT.

Yarding output, the chief element determining cost, is of utmost concern to both the operator and the timber appraiser. Influenced as it is by a great variety of factors, it is hard to estimate. Companies that use a bonus system have proved that abundantly, and they possess every advantage in the shape of records and time, aside from the inducement to make an intensive examination of the territory. The appraiser, who must estimate yarding output at wholesale and after a far less thorough examination, is at a great disadvantage. Following are the factors to be considered. No attempt is made to present them in the order of their importance. They are treated in more detail under the specific methods.

(1) *Methods.*—As will be shown later, each of the different methods is adapted to specific sets of conditions. As a practical logging question, however, it is not always clear which method should be employed. For example, one operator may be securing as good results with the ground method as another operator is securing with the high-lead or overhead method, under practically the same conditions. In some cases, the use of the best method may be out of the question because a machine adapted for it is not at hand, and the amount of timber to be moved does not justify the purchase of new equipment.

(2) *Yarding direction as it relates to the slope of the ground.*—With any method the yarding output is largest on level ground, or on ground sloping moderately toward the yarding engine. The drawback to yarding logs downhill with a ground method is that as soon as gravity carries the low forward faster than the haul-in or main line is traveling, the tendency is for the log or logs to run out of their chokers or to run behind stumps or débris on the side opposite to that on which the line is leading. As a general thing the output with a ground method is from 30 to 50 per cent higher when the logs are moved uphill than when they are moved downhill; assuming, of course, that the ground in question is steep enough in places to cause the logs to run when being yarded downhill, and that the equipment is powerful enough to handle the logs uphill with dispatch. Overhead yarding methods, taking them straight through, work better downhill than uphill. In fact, this method is especially adapted for yarding logs down long, steep slopes.

(3) *Size of timber.*—With the same conditions and within certain limits, the yarding output is less and the load that can be yarded at one trip is less in small timber than in large. A certain amount of time is consumed in making a yarding trip regardless of the number of logs or the volume of timber hauled, since in any event approximately the same amount of time is lost in hooking up, starting, unhooking, and returning the trip line to the woods. Logs of large diameter, assuming that the motive power is ample, are less likely to hang up than small ones. In ground yarding there is special advantage in large timber because it is ordinarily not practical to handle as many logs at a trip as with the overhead, or even with the high-lead method. Under certain conditions, particularly with the overhead and high-lead methods, the effect of small timber on the output may be to some extent offset by cutting long logs. Of course, with fast machinery and relatively larger crews, the yarding output in small timber can be made to approach that in large.

(4) *Yarding distance.*—The general principle is clear and indubitable that the longer the distance over which timber must be conveyed, the less will be the output. It is not directly in propor-

tion to the distance, however, as a large part of the time is consumed in hooking, starting, unhooking, and the like, which is the same whatever the distance.

The economic range, of course, varies with the style of yarding. The high lead affords its peculiar advantages only when confined to a distance of from 500 to 700 feet; ground yarding is generally worked on a maximum of from 600 to 900 feet; while the overhead systems are worked to best advantage on longer reaches, say from 900 to 1,500 feet. Of course, it is sometimes necessary and advisable to use these systems, particularly the latter, at greater distances.

The less of the total burden of transportation assigned to the railroad, the more comes on the yarding, increasing the distance and lowering the output. So the topography of the country has a great deal to do with fixing the yarding distance. While it is possible to build railroads nearly everywhere, it is not always practical to do so because of the high cost of grading and maintaining the track, the large investment, and the danger and high cost of operating trains on heavy grades. The volume of the stand affects the yarding distance in much the same way, as more miles of spur railroad can economically be built where the stand is heavy than where it is light.

(5) *Size of crew.*—Up to a certain point the output increases as the size of the crew is increased. On the other hand, a relatively large output due to a large crew is not necessarily the most economical. Too much can be made of this factor, since, with any system of yarding, the bulk of the crew is largely fixed. For example, in the case of ground yarding, the crew, as a rule, consists of 11 men. This type of crew is more or less elastic in its makeup, however, as ground yarding crews consisting of as many as 14 are used; others contain as few as nine men.

(6) *Condition and care of equipment.*—The output varies with the condition of the equipment, the way it is used, and the length of life expected of it. It is larger when up-to-date machines of the proper size rather than old machines of the wrong size are used, when machines are driven at practically their maximum speed instead of slowly for the purpose of prolonging their life and reducing the cost of maintaining them, and when lines, rigging, etc., are replaced as soon as the signs of wear indicate that they may break, instead of waiting for them to break a number of times before being replaced. There must, of course, be a nice balance between the output and the labor, equipment—maintenance and depreciation—and supply costs per thousand feet. Most operators, no doubt, get as close to this balance as is possible. There are some, however, who could reduce the total cost per thousand feet for yarding by taking better care of the equipment; others who could reduce the cost by speeding up the

engines, if possible, or by securing engines that would stand harder work.

(7) *Loss of time.*—There is of necessity considerable lost time in yarding. Yarding engines have to be moved from one landing to another and from one end of a given landing to the other. Lines have to be run out, and, as the work progresses, changed from one yarding trail to another. These and other delays are necessary. Loss of time results from other causes, such as the inability of the loading department, or the next step in transportation, to handle the yarding output at all times. The aim of camp foremen is to reduce to the minimum the loss of time because of necessary delays and to eliminate unnecessary delays entirely.

A few operators in their endeavor to take care of this factor properly keep a record of lost time. The following is a summary of one of these records for three donkey engines, based on a logging period of six months:

Record of lost time in yarding.

Waiting for trucks, 40 hours	days	4
Moving yarders, 240 hours	do	24
Changing ends, 90 hours	do	9
Total loss, 370 hours	do	37
Total number of landings		27
Average time lost in moving a yarder from one landing to another	hours	8.9
Average time lost in changing ends	do	3⅓
Average amount of timber yarded to a landing	feet	830,000
Number of yarding days		383
Number of productive yarding days		346

(8) *Amount of defect in timber.*—The yarding output is affected in much the same way by rot as by the size of the timber. It takes as much time to yard a rotten log as a sound one of the same size, and yet the rotten log may not scale more than half as much as the sound one. Much yarding time is lost in disentangling the logs that should by utilized from those that are worthless. The operator has to fell and buck the defective timber—sometimes half the stand—to make sure that no merchantable timber is left. Few factors, either as related to the cost of yarding or the operation as a whole, are so important or so often overlooked as this one.

(9) *Surface of the ground.*—The output with the ground-yarding method is less where the ground is broken up with "potholes," hummocks, small ravines, and the like, than where the ground is relatively smooth. The effect of this factor on the output with the high-lead and overhead methods is not so apparent, particularly with the overhead method.

GROUND YARDING.

Up to within the last year or so the bulk of the timber was yarded by the ground system. Available information does not indicate how much is handled by this system at present. That it has been replaced to a considerable extent by the high-lead and overhead systems is clear. This system of yarding was long the one standard system, and it is the system which present-day operators know best. For this reason it is here treated at greater length than the other systems; indeed, the discussion of ground yarding is made to serve as a basis for the discussion of high-lead and overhead systems.

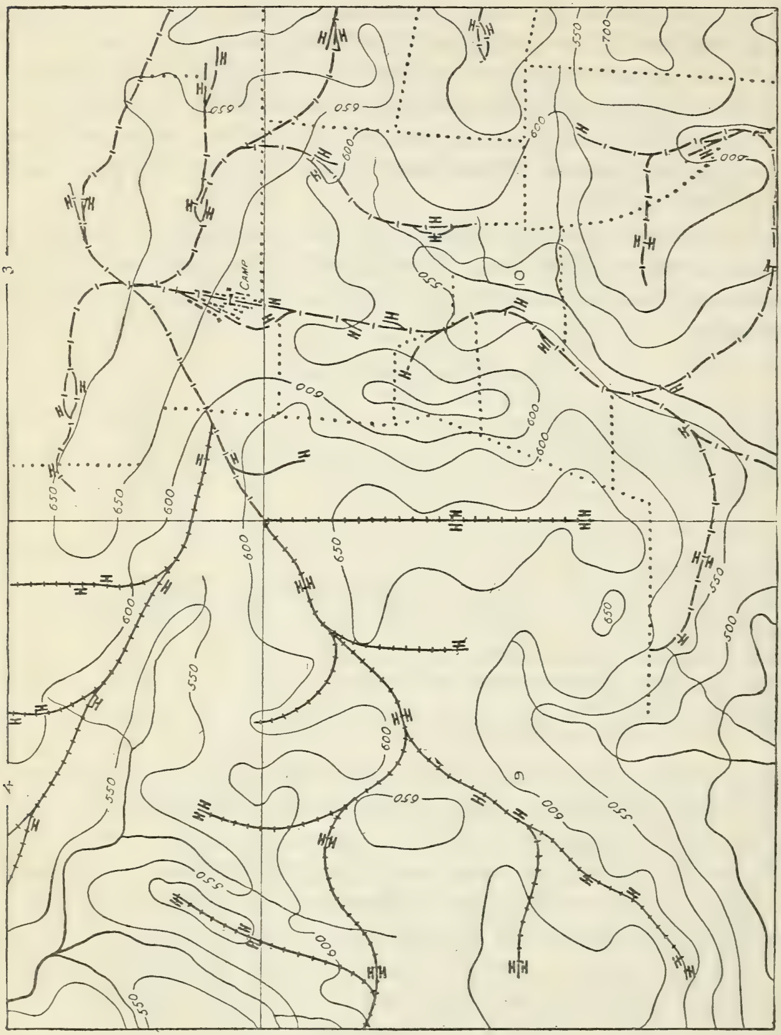

FIG. 16.—Yarding chance in exceptionally good ground.

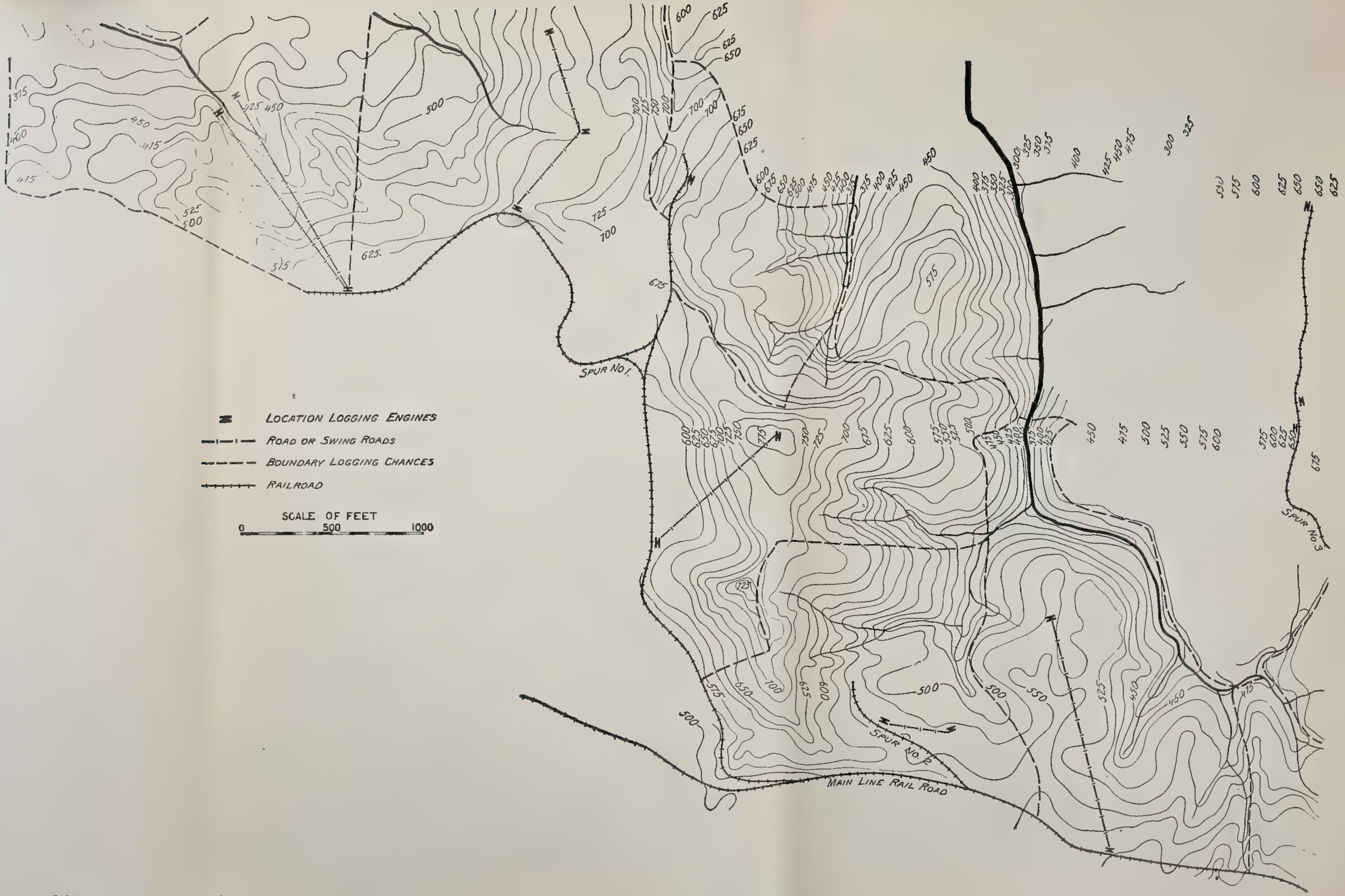

Fig. 17.—Yarding chance in rough, steep ground.

SHAPE AND SIZE OF YARDING CHANCE.

The shape of yarding chances, or the timber yarded to one point by one yarding engine, depends on the topography of the land. If the land is practically level, making it possible to gridiron the tract with railroads rather regularly laid out, the yarding chances are rectangular in shape, with the side bordering on the railroad about twice the length of the ends. This results in a square tract being yarded to each end of the landing. Seldom, however, does the topography permit the blocking of yarding chances in this manner. As a rule they are very irregular in shape, being bounded by divides, gulches, or the range of practical yarding distance. Figure 16 shows the shape of yarding chances in exceptionally good ground, while figure 17 illustrates the usual irregularity. The chances in the latter case are larger than ordinary.

YARDING DISTANCE.

It is not practical in the abstract to say anything that will indicate the economical maximum yarding distance. Judging from the practice, the distance with the ground-yarding method ranges, under favorable conditions, between 600 and 900 feet, being generally about 800 feet. If conditions are particularly favorable from the standpoint of the volume of the stand and the cost of railroad construction and operation, the distance may be reduced to 500 feet. Too often, as has been pointed out, the topography of the country, by fixing the railroad location, fixes the distance that the timber must be transported by logging engines. In a given case it may be too long to constitute an economical yarding distance and not long enough to justify double hauling. It is then good practice to yard a distance greater than 900 feet.

An important factor influencing the yarding distance, from the standpoint of both railroad and yarding costs, is the average stand of timber per acre. The following distances have been recommended as a general basis of calculation:

(1) Twenty to forty thousand feet of timber per acre, 1,200 feet maximum yarding distance.

(2) Forty to sixty thousand feet of timber per acre, 1,100 feet maximum yarding distance.

(3) Sixty to eighty thousand feet of timber per acre, 1,000 feet maximum yarding distance.

(4) Eighty to one hundred thousand feet of timber per acre, 900 feet maximum yarding distance.

LOCATION OF YARDING ENGINE SETTING.

The location of the landing or yarding engine setting may be determined by the hook tender, the camp foreman, or jointly by the camp foreman and superintendent. In certain cases the hook tender may shift the settings made by the foreman or superintendent. Where this is permitted, the hook tender is held responsible for any reduction in the output because of an improper setting. In many cases the settings are selected by either the superintendent or foreman, the exigencies of the situation making a conference impractical. Where possible, the superintendent and foreman together should make the selections.

There are logging superintendents and foremen who feel that their success in securing large yarding outputs is largely due to the fact that they exercise the utmost care in blocking out yarding chances and locating settings. When ground conditions permit, the best settings are selected and the railroad is then located in relation to them, instead of the railroad being located first and the chance taken that satisfactory settings can be found along it. In other words, what should be the best railroad location from the standpoint of cheapness of construction and operation would not necessarily be the best location from the standpoint of the total cost of the combined yarding and railroad hauls. Cases can be found where the cost of a piece of spur railroad was excessive because of a location of this kind, the more expensive location being made seemingly for the purpose of securing the best yarding setting, which in turn enabled the yarding crew to get at least the standard output expected of them. Of course, aside from this, any additional output resulting from special railroad construction had the effect of decreasing the cost per thousand feet of succeeding steps in the logging operation.

Where logs are yarded direct to a railroad, the settings, in addition to being where the largest average yarding output can be secured, should be where the logs can be loaded to the cars with dispatch.

MOVING GROUND YARDING ENGINES.

The time lost in moving engines reduces the actual yarding time, and any saving in time in making the engine moves has the effect of increasing the yarding output. It generally takes from 5 to 10 hours to move a logging engine from one setting to another, depending for the most part on whether it is transported on a flat car or dragged over the ground. In one camp the average time, when based on an operating period of six months, amounted to nine hours. The work included moving the engines, raising gin poles for loading purposes, and setting lines. A yarding crew in a camp along the Columbia River loaded the engine on a flat car, moved to a new landing, set the lines, and yarded 54 logs in one day. A hook tender in a camp on the west slope of the Cascades moved a yarding engine over the ground a distance of 2,500 feet in 10 hours with a yarding crew of 11 men. Half the move was made up a grade of 40 per cent. The ground was practically clear of chunks of trees.

From two to four hours' time is consumed in moving the engine from one end of the landing to the other. In one camp in Washington where the ground was practically level the average time, when based on a six months' operating period, was three and one-third hours. This included running out the lines. A crew in a camp along the Columbia River changed ends and ran the trip line around a week's yarding in 2 hours and 10 minutes. The ground conditions were favorable. Another crew in the same region changed ends and ran the trip line out in 1 hour and 25 minutes. The ground was exceptionally good. Another hook tender in the same region changed ends and yarded 78,000 feet in a day, two and one-half hours being consumed in changing ends.

The actual cost of moving engines is not so large where the work is performed by the crew that clears the right of way and constructs landings, or by a special crew. With the ability to move logging engines as one of the qualifications of the hook tender in charge of the logging engine moving crew, the move is made more quickly. The daily cost of this crew is not so large as that of a regular yarding crew.

One method of reducing the loss of time is the use of an extra yarding engine and, if the motive power for loading is furnished by a separate engine, an extra loading engine, so that all a crew has to do when it has completed the yarding of the timber tributary to a landing is to move the small equipment to the new landing where the extra equipment has been put in place. The move by this method should take about 30 minutes. At a convenient time the crew that is engaged in clearing rights of way and building landings, or a small special crew, moves the extra equipment to the new landing and runs out the lines. The hook tender, who is to yard the timber, may supervise the work of placing the lines. Just before the move is made the fireman of the yarding crew goes ahead to raise steam in the extra machines and have everything in readiness so that yarding can proceed as soon as the rest of the yarding crew arrive.

There are other reasons than the increased yarding output for using extra equipment. The daily cost of the operations following yarding is to a great extent fixed. When a yarding crew is moving from one side to another the output from the camp is curtailed. The longer it takes to make the move the greater the curtailment. This curtailment has the effect of increasing the unit cost of succeeding steps in the operation. In the case of a two-side camp the output is cut in two during the time the move is being made, so that the unit cost of succeeding steps is practically doubled. Extra yarding equipment also gives the man who looks after the machinery an opportunity to examine the idle machinery and see that everything is in good running condition, thus adding to the safety of the operation and reducing to a minimum the chance of tying up a yarding crew because of a breakdown, or, if breakdowns occur, the crew can change to a machine already set so as to lose no time in waiting for repairs to be made.

The practice of using an extra yarder in the above-mentioned manner is not common, and no operator running less than three sides would consider it desirable.

SETTING THE LINES.

With the boundaries of the yarding chance known and the yarding engine placed in position at one end of the landing, the yarding crew sets about running out the main and return lines. The first step is to locate the first yarding road. If all the timber on the chance is felled, and it usually is, the usual practice is to locate the first road, which is really not a road but the route the logs will follow to the landing, on the side bordering the railroad, succeeding roads following each other right around the chance. These roads radiate in a half circle from the center to the border of the chance. Since the roads lead directly to the landing, it is not necessary to locate them in advance, except in a general way. Figure 18 shows the location of the yarding roads.

After the first road is located the straw line is dragged by hand over the road from the yarding engine and passed through a block, which is adjusted to a tail tree at the far end of the road. From there it is taken 300 feet or more to the right or left, depending on the direction the chance is being worked, along the back boundary of the chance and through another block, and then on to the yarder. At the yarding engine, the end of the straw line which has just been dragged in is attached to the trip line and the other end is reeled in on the small drum. This drags the trip line out to and through the blocks and back over the road to the yarder. The straw line is then detached and the end of the main line attached to the trip line by means of a clevis. The yarder is now ready for operation.

In changing from one road to another the method in general is the same. Before the crew gets ready to change to a new road the hook tender may, with the aid of one of the choker setters and the sniper, run out the straw line on the new road and hang the extra head block.

Then, as soon as the last log is on the old road, the chaser unhooks the trip line from the main line and sends it back. When it reaches the new tail tree the hook tender is there to attach it to the straw line and send it in over the new road to the yarder, where it is attached to the main line. By the time the crew has moved up to the front of the new road the butt chain has arrived, thus enabling them to start hauling logs again with practically no loss of time.

Until quite recently the trip line was run out and changed from one road to another by hand, and in some camps this method is still used because of the character of the yarding engines. All operators that have used a straw line, which should consist of ⅜-inch plow-steel cable, are convinced that it is a valuable piece of equipment, especially in rough, steep ground. It has been estimated that it increases the yarding output from 10 to 15 per cent.

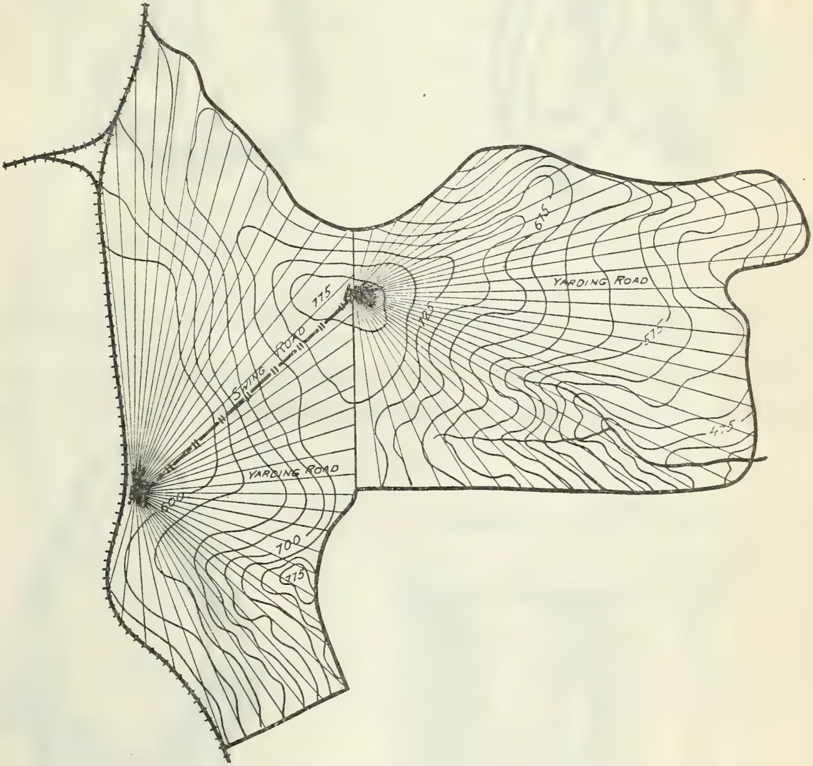

FIG. 18.—Logging chance showing location of ground yarding roads.

In addition to the two head trip blocks (fig. 19), which are hung to the tail trees by means of straps made from short pieces of cable, it may be necessary to reduce wear and tear on the trip line, to use two or three other trip-line side blocks (fig. 20), either between the tail trees or between the second tail tree and the yarder. The placing of the trip line several roads distant from that being logged obviates frequent change in its position and also keeps it out of the way of the logs as they are hauled in.

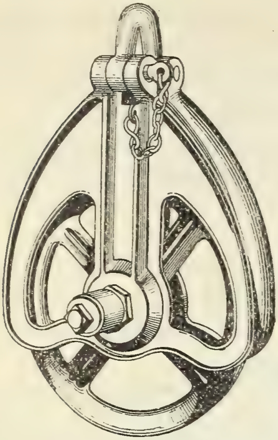

FIG. 19.—Trip line head block.

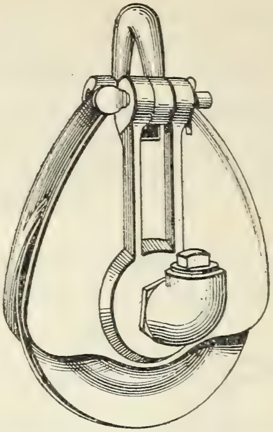

FIG. 20.—Trip line side block.

The set-up described above has the main line leading straight from the main drum, through the main-line fairleader (fig. 21), across the landing, and out along the road to the timber. Only a small percentage of the timber can be yarded with the lines leading in this way. Most of the roads will form an angle with an imaginary line

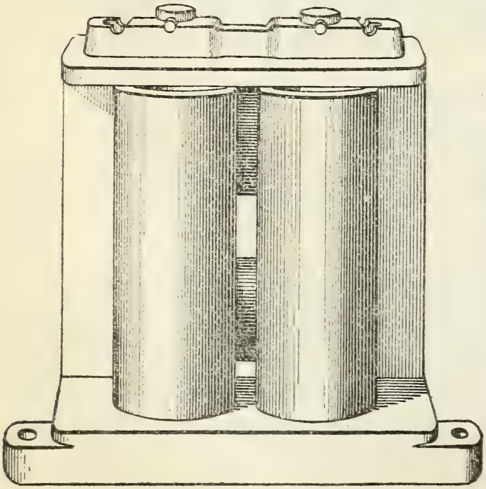

FIG. 21.—Main-line fairleader.

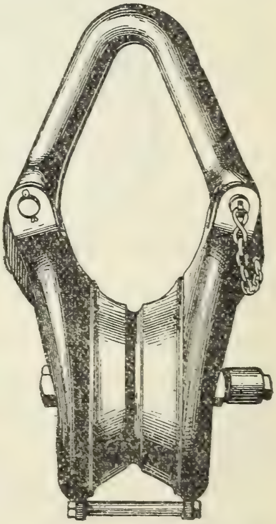

FIG. 22.—Butt chain lead block.

run from the main-line drum across the middle of the landing, some of the angles formed being a little larger than a right angle. This difficulty is generally overcome by leading the main line through a butt-chain block (fig. 22) hung to a stump standing in line with the yarder and landing and 50 feet or more from the approach end of the landing. In operation the log is yarded to the butt-chain block, the chokers are all unhooked from the butt chain, permitting the butt chain to be passed through the block. The chokers are again hooked to the butt chain and the log continues on its way to the landing.

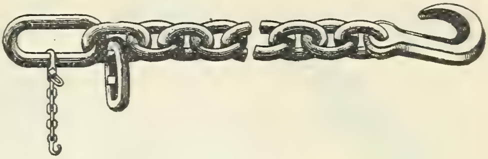

Fig. 23.—Butt chain.

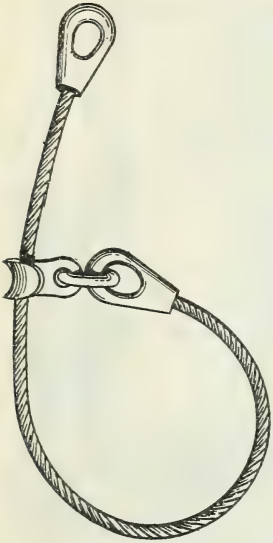

Fig. 24.—Choker with socket.

OPERATION.

After the ground around the landing has been freed of large chunks of waste material, the butt chain (fig. 23) attached to the main line is run out to the first log on the new road. The choker men put the chokers (figs. 24 and 25) around the end of the logs. After the load has been connected to the butt chain, the hook tender or head-rigging slinger signals for the engineer to haul in on the cable and the load starts down the road. When it reaches the butt-chain block, as it will in most cases, the chaser signals for the engine to stop, unhooks the chokers from the butt chain, pulls the butt chain through the butt-chain block, rehooks the chokers to the butt chain, and signals for the engineer to go ahead. The load is then dragged to the landing, where it is disconnected by the chaser, or in rare cases, by one of the loaders.

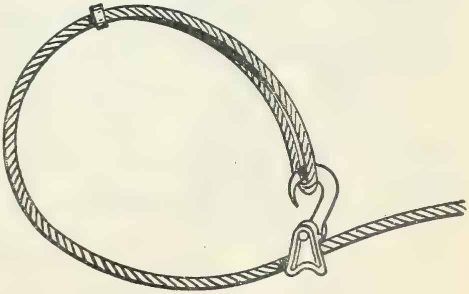

Fig. 25.—Choker with eye.

Where the logs are large, only one is hauled at a trip. In other cases it may be practical to yard as many as six. In general, the number depends on the volume of the logs, the size of the equipment, and the ground conditions.

As a rule, one choker is used with each log. One, two, and occasionally three, chokers are attached to a butt chain. Where more than one butt chain is required, a rigging plate (fig. 26), to which a second butt chain is attached, is inserted in the main line about 50 or 60 feet from the end of the main line or the point to which the usual butt chain is attached, the distance depending on the length of the longest logs hauled.

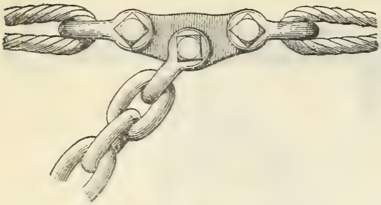
FIG. 26.—Rigging plate.

Occasionally, it is necessary to use a yarding block (fig. 27) to side line the logs around stumps or other obstructions, or to pull them backwards until they are clear. In the case of exceptionally large logs it is sometimes necessary to increase the power of the yarding engine by the use of a yarding block. When this is done, the end of the main line is attached to a tree along the road at some distance from the log in the direction of the yarding engine, a yarding block is hung in the bight of the line, and the shackle of the block is attached to the log. After the log has been moved up to the point where the line is attached to a tree, a new "tail-hold" is taken on another tree nearer the yarder.

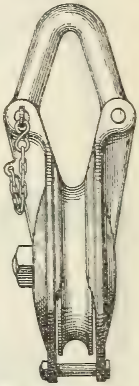
FIG. 27.—Yarding block.

The butt chain lead block, or bull block, has been replaced to some extent by yarding or stump rollers (fig. 28). This device allows the same speed with less friction, and does away with the services of one man. By placing three rollers on the arc of a circle, it is possible and practical to log directly back of the landing without the use of a lead block. It has been estimated by an operator that the use of these rollers instead of lead blocks increases the output of a yarding crew between 9 and 10 logs per day, not taking into account the fact that the crew is reduced by one man. Of course, there are many chances where the use of a stump roller would not be practical.

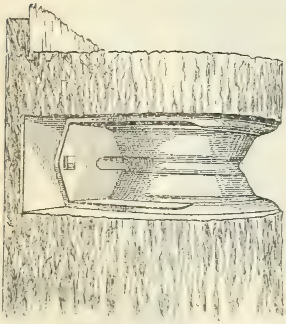
FIG. 28.—Yarding or stump roller.

ORGANIZATION OF CREW.

The number of men in a ground-yarding crew varies by camps and in the same camp by chances. The usual crew consists of the following men:

1 hook tender.
1 swamper.
1 sniper.
2 rigging slingers.
2 choker men.
1 chaser.
1 signal man.
1 engineer.
1 fireman.
1 wood buck.

In some cases only one rigging slinger is used. Where the haul is long and the ground particularly rough, an additional choker man may be necessary. Sometimes two wood bucks are required. If oil is used as a fuel, a wood buck and, in some cases, a fireman are not needed.

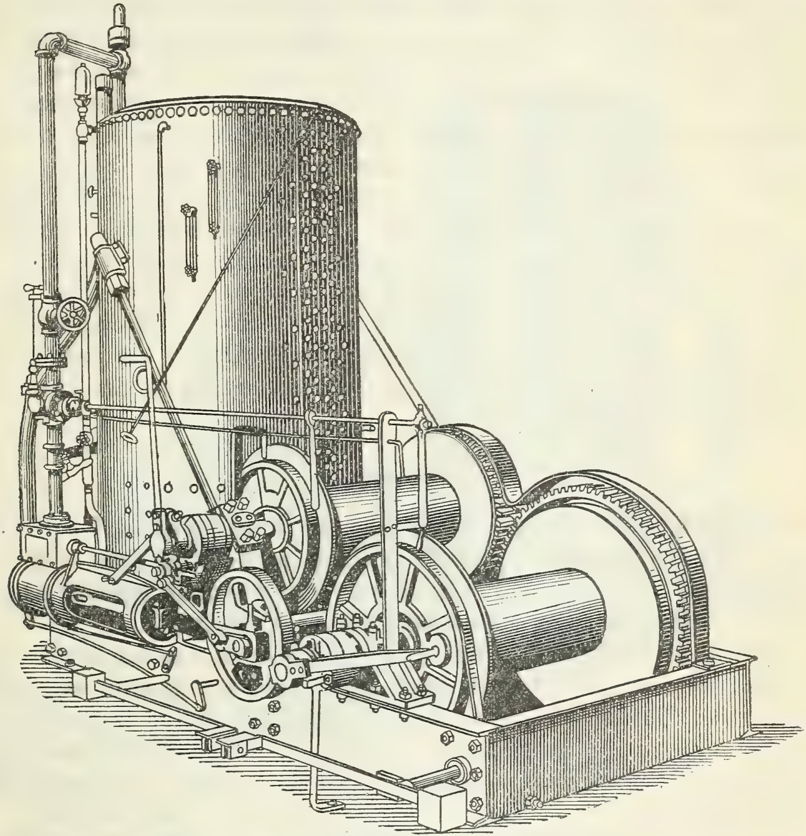

FIG. 29.—Combination road and yarding engine.

The division of labor in a yarding crew is not always clear. The different members of the crew do what the situation demands. The hook tender is in charge of the crew, and the amount of work done depends largely on his ability. He plans the work, locates the roads, instructs the crew as to the character of the timber that should be hauled, designates the order in which the logs are to be taken, and assists the rigging slingers with their work. The swamper works just ahead of the rigging men, knots the logs, fells small timber that may be a source of danger to the crew, chops out the brush, and improves the roads, so that the logs can be brought out without being hung up. When necessary, the sniper rounds off the under side of the front end of the logs, so that they will slide over obstructions. In rough country, where the logs are apt to roll and to be dragged first on one side and then on the other, they are usually sniped all the way around. The depth of the snipe depends partly on the size of the log and partly on the ground conditions, ranging from little or nothing to 9 inches. The head rigging slinger is the hook tender's assistant. Working alone or assisted by another rigging slinger, sometimes two others, he unhooks the chokers from the butt chain when the main line is returned, hooks up the new load of logs, and starts it toward the landing. The principal duty of the choker men is to put the chokers around the logs. The chaser, standing near the butt chain block, signals to the engineer in case there is need for stopping the engine. His principal work is to pass the load of logs by the butt-chain block. The signal man, by means of signals, usually given by pulling on a wire attached to the whistle of the yarder or by an electrical device, transmits the order of the hook tender, rigging slinger, or chaser to the engineer.

EQUIPMENT.

Ground logging engines.—Engines used in swinging and roading on the ground, as well as ground yarding engines, are dealt with in this section. While their inclusion here is not exactly logical, clearness and convenience of discussion make it advisable.

Figures 29 and 30 show the compound-geared and tandem-drum logging engines, the two standard types used for ground logging. As a rule, the narrow-drum, compound-geared engine is used, the compounding of the gears having proved the best method of securing the proper relation between the two drums in regard to speed and pulling power.

The wide-drum, simple-geared engine is also used, but principally for swinging and roading, where high speed in the lines and large drum capacity are of major importance. Wide-drum engines bear special trade names, depending on whether they are adapted for yarding and swinging or roading, the chief differences lying in the drum proportions and friction devices. The engines and boilers of a long-haul road engine are, of course, larger than those of an engine adapted to haul at relatively shorter distances.

Probably no other class of machinery is called upon for such extremely severe service as logging engines. The demands made upon them are frequently far beyond their normal capacity. To see them hauling logs larger than 10 feet in diameter and 24 feet in length over rough ground on a "straight" line is to marvel that they are not wrecked in a short time. That they are not is due to the fact that they are simply, compactly, and powerfully built of the best adapted material. The frame or bed of the machine, on which the security of all fastenings and the permanency of alignments of all working parts depend, is strong and rigid, being made of the heaviest standard section of steel beams spaced by heavy crossbars of cast iron or steel.

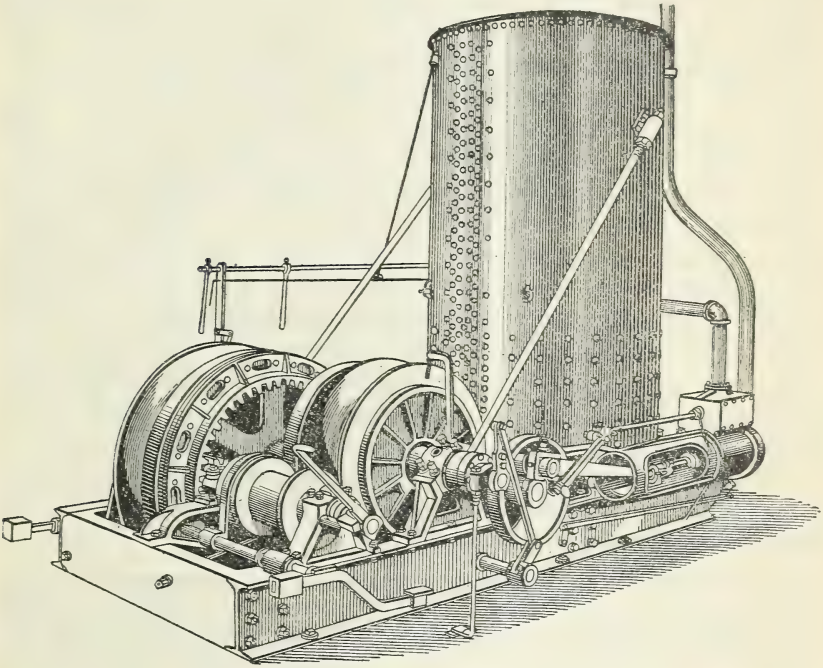

FIG. 30.—Compound-geared yarding engine.

Logging engines are equipped with high-pressure boilers of the vertical type, built of 60,000-pound flange steel. They have a working pressure of from 150 to 200 pounds (generally 200 pounds), and are guaranteed to pass Hartford inspection. They range in size from 48 inches in diameter and 96 inches in height to 80 inches in diameter and 153 inches in height.

The extreme height and high working pressure of these boilers, the limits of which have been reached, is the result of constant increase in the cylinder sizes. The width of the engine frame, by limiting the diameter of the boiler, has restricted the dimensions of the round fire box, resulting in too small a proportion of grate to heating surface. To overcome the steaming difficulties resulting from insufficient grate area, most new logging engines are equipped with a fire box which is oblong or elliptical in shape and extends about 2 feet beyond the cylindrical portion of the boiler on the front side. This design increases the grate area considerably without correspondingly increasing the width of the engine frame.

All of the engines are double—that is, have two cylinders. Ordinarily, logging engines are classified by the size of the cylinders, the diameter being given first. A glance at Table 7 shows the range of sizes. The engines are of the heavy-duty type, the valves and valve gear differing with the make.

Standard drum engines have two drums, placed either tandem or opposite, or nearly so. These rotate upon their shafts and are held fast when pulling by means of frictions. Several types of frictions are used. They are operated either by hand or steam, the steam friction being particularly desirable on the larger engines. The main, or hauling, drum is made of steel; the trip drum, which carries the trip, or return line, is made of semisteel. These engines can be equipped with loading and straw-line drums, driven either by their own gear or pinions or by a chain drive. In the case of the simple-geared engine, the cut-steel gears of the main and trip drums are driven by a cut-steel pinion on the engine crank shaft. The trip drum of the compound-geared engine is driven in a similar way. The main drum in the latter type, however, is driven through a compound train of gears by an internal or external gear, a second pinion keyed on the trip-drum shaft driving the gear of the main-drum shaft.

The standardization committee on logging engines of the Pacific Logging Congress recommended that the following definitions and formulas be adopted as standard:

(*a*) *Right and left hand sides of a logging engine.*—When standing at the boiler end of the engine and facing out over the drum, that side of the machine to the right is termed the right-hand side and that to the left is termed the left-hand side. In general, the engine is operated from the right-hand side. This is frequently called the "engineer's side."

(*b*) *Main and trip drums.*—The main drum is the drum which is used to haul in the load. This is sometimes called the forward or the lower drum. The drum which is used to return the main hauling line is the trip drum, also called the haul-back drum.

(*c*) *Rope capacity.*—The rope capacity of the main drum and trip drum must bear a more or less definite relation. On road engines the trip-drum capacity should be not less than twice the capacity of the main drum, and so far as practicable there should be approximately six or seven hundred feet of additional capacity on the trip drum. On yarding engines the capacity of the trip drum should be at least two and one-fourth times that of the main drum, and so far as practicable this ratio should be slightly increased. To find the drum capacity the following formula is used:

$$\text{Capacity} = C \times L \times \frac{D+d}{2} \times \frac{D-d}{2}.$$

D equals diameter of flange, in inches.
d equals diameter of barrel, in inches.
L equals length between the flanges, in inches.
C equals constant, varying for each size of line.

Value of C.

Size of line.	Constant.	Size of line.	Constant.
$\frac{1}{4}$ inch	4.16	1 inch	0.262
$\frac{5}{16}$ inch	2.67	$1\frac{1}{8}$ inches	.207
$\frac{3}{8}$ inch	1.86	$1\frac{1}{4}$ inches	.167
$\frac{7}{16}$ inch	1.37	$1\frac{3}{8}$ inches	.138
$\frac{1}{2}$ inch	1.05	$1\frac{1}{2}$ inches	.116
$\frac{9}{16}$ inch	.828	$1\frac{5}{8}$ inches	.099
$\frac{5}{8}$ inch	.672	$1\frac{3}{4}$ inches	.085
$\frac{3}{4}$ inch	.465	$1\frac{7}{8}$ inches	.074
$\frac{7}{8}$ inch	.342	2 inches	.066

Using the above formula, the drum capacity is obtained by multiplying the sum of one-half the diameter of the flanges and one-half the diameter of the barrel by the difference between one-half of the diameter of the flanges and one-half the diameter of the barrel by the length between the flanges and the constant for the size of the line required. Five-eighths inch line is almost universally used for trip lines. The main line varies from 1 inch to $1\frac{5}{8}$ inches in diameter.

In computing the proportion between the main drum and the trip-drum rope capacities it is assumed that the main line is $1\frac{1}{4}$ inches and the trip line $\frac{5}{8}$ inch.

(*d*) As a matter of relative comparison only, the speed of any line is the speed of the line when the drum is one-half full of cable and engine is running at a piston speed of 600 feet per minute.

(*e*) *Standard logging engine.*—What is known as a standard logging engine is a two-drum machine complete with boiler, hood, stack, spark arrester, and one gypsy head. Patented spark arresters, straw-line and loading drums, and the like, are additional equipment, and usually are furnished at extra cost. In the case of narrow drum yarders where a true lead is necessary on the drums, one main line and one trip line fair-leader should be furnished with each engine.

(*f*) *Boilers.*—The working pressure of boilers 48 inches or larger in diameter should not be less than 175 pounds. Boilers are rated by their inside diameters and the over-all length of effective shell. Any extension below the water leg for the ash pan or any extension above the tube sheet for the breeching is not considered part of the effective shell.

(*g*) *Pulling power.*—The pulling power of any drum can be obtained by the following formula:

$$W=\frac{r\times G\times P\times A}{R}$$

W=Weight or pull on cable.
P=Full boiler pressure.
A=Area of one cylinder.
r=Radius of crank.
R=Radius of drum.
G=Gear ratio drum.

The size of yarding engines varies in different camps. An operator who has given more than the usual amount of attention to this question, and who has a reputation for consistently securing large yarding outputs, made the following recommendations, based on uphill yarding:

(*a*) A 10 by 11 inch compound-geared, high-speed yarding engine of any standard make to be used in yarding timber on practically flat ground where the yarding distance does not exceed 1,000 feet, the difference in elevation over the yarding area does not exceed 75 feet, and the volume of the largest logs does not exceed 1,000 feet.

(*b*) An 11 by 13 inch compound-geared, high-speed yarding engine of any standard make to be used in yarding timber on rolling ground where the yarding distance does not exceed 1,000 feet, the difference in elevation over the yarding area does not exceed 150 feet, and the volume of the largest logs does not exceed 5,000 feet.

(*c*) A 12 by 14 inch compound-geared yarding engine of any standard make to be used where conditions are more severe than those stated above.

(*d*) The engines to be equipped with high-pressure boilers of large capacity and three drums.

The following gives the sizes of engines used in several camps:

(*a*) Compound-geared 11 by 13 inch yarding engines are used. They are new, and equipped with the extended fire box. The logging superintendent is considered one of the most efficient on the coast. The country is mountainous, rough, and badly broken up. The slopes in general are steep. Logs were moved both uphill and downhill; uphill when possible. They averaged about 2,000 feet in volume, and logs containing from 7,000 to 8,000 feet were not uncommon.

(*b*) Compound-geared 10 by 11 inch yarding engines were used. They were new, and had extended fire boxes. The ground was quite flat, regular, and relatively free of brush and down timber. The logs averaged about 600 feet in volume. Never less than two, sometimes three, and occassionally four logs were yarded at a trip.

(*c*) Compound-geared 10½ by 10¼ inch yarding engines were used. The timber was second growth, dense, and of fair height, averaging about 30 inches D. B. H. The logs averaged about 600 feet in volume. The ground was practically level and quite free of ravines, pot holes, brush, and down timber.

(*d*) Compound-geared 12 by 12 inch yarding engines were used. The country was mountainous and badly broken up, being considered a hard chance. The logs, including cedar slabs, averaged 1,200 feet in volume, but logs ranging from 5,000 to 7,000 feet in volume were not uncommon.

(*e*) Small engines are being replaced by high-speed, 11 by 13 inch compound-geared engines. The country is rough, the logs averaging 1,000 feet in volume. Some of the logs scale 5,000 feet.

The prices of logging engines are given in the following tables. They are those of March, 1916. The prices given do not include fair-leaders, loading or straw-line drums, the extended fire box, or other special devices.

TABLE 8.—*Prices of compound-geared yarding engines.*

Size of engines.	Capacity of drums.		Size of boilers (circular).	Speed of lines.	Weight.	Net price f. o. b. Portland, Tacoma, and Seattle.
Inches.	*Feet.*	*Size of line, inches.*	*Inches.*	*Feet per minute.*	*Pounds.*	
10 by 10½	Main, 1,470 Trip, 3,375	1⅛ ⅝	62 by 132 high	Main, 270 Trip, 1,100	34,500	$3,450
10 by 11	Main, 1,700 Trip, 3,700 Straw, 3,700.	1⅛ ⅝ 5/16	66 by 125 high	Main, 265 Trip, 790	33,500	3,350
10 by 12	Main, 950 Trip, 2,460	1⅛ ⅝	54 by 125 high	Main, 260 Trip, 575	29,000	3,390
11 by 12	Main, 1,400 Trip, 3,500 Straw, 3,375.	1¼ ⅝ 5/16	68 by 144 high	Main, 320 Trip, 1,210	44,500	4,450
11 by 13	Main, 1,500 Trip, 4,050 Straw, 4,000.	1¼ ⅝ 5/16	66 by 125 high	Main, 259 Trip, 695	40,000	4,000
12 by 12	Main, 1,400 Trip, 3,500 Straw, 3,375.	1¼ ⅝ 5/16	68 by 144 high	Main, 320 Trip, 1,210	46,000	4,600
12 by 13	Main, 1,500 Trip, 3,400 Straw, 3,375.	1¼ ⅝ 5/16	74 by 144 high	Main, 330 Trip, 1,400	53,000	5,300
12¼ by 12	Main, 1,760 Trip, 3,900	1¼ ⅝	68 by 147 high	Main, 275 Trip, 930	45,000	4,580
12 by 14	Main, 1,840 Trip, 5,500 Straw, 5,500.	1⅜ ⅝ 5/16	72 by 144½ high	Main, 237 Trip, 665	50,000	5,000
12 by 14 (special)	Main, 1,900 Trip, 5,500 Straw, 5,500.	1¼ ⅝ 5/16	72 by 144½ high	Main, 285 Trip, 665	50,000	5,000
12 by 13	Main, 1,500 Trip, 3,900	1⅜ ⅝	68 by 144 high, extended fire box.	Main, 275 Trip, 930	49,000	5,330
13 by 13	Main, 1,500 Trip, 3,400 Straw, 3,375.	1¼ ⅝ 5/16	74 by 144 high	Main, 330 Trip, 1,440	54,500	5,450
13 by 13	Main, 1,500 Trip, 3,900	1⅜ ⅝	68 by 144 high, extended fire box.	Main, 275 Trip, 930	51,000	5,065

The capacity of the drums in Table 8 is for one size of rope. The following table shows the approximate capacity of the main drums of the engines given in ropes of other sizes that may be used. The order is the same in both tables.

TABLE 9.—*Length of rope for compound-gearing yarding engines.*

Engine.	Diameter of rope (inches).				Engine.	Diameter of rope (inches).			
	1	1⅛	1¼	1⅜		1	1⅛	1¼	1⅜
	Length of rope.					Length of rope.			
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
10½ by 10	1,800	1,470	1,270	....	12 by 13	....	1,840	1,500	1,225
10 by 11	2,100	1,700	1,350	....	12¼ by 12	....	1,570	1,250	1,030
10 by 12	1,275	1,000	850	....	12 by 14	....	2,750	2,220	1,840
11 by 12	2,200	1,750	1,400	....	12 by 14 (special)	....	2,370	1,900	1,570
11 by 13	....	1,730	1,500	1,220	12 by 13	....	1,840	1,500	1,225
12 by 12	....	1,770	1,400	1,200	13 by 13	....	1,840	1,500	1,225

TABLE 10.—*Tandem drum logging engines.*

Capacity of drums.			Size of boilers.	Speed of lines.	Weight.	Net price f. o. b. Portland, Tacoma, or Seattle.
Dimensions.	Size of line.					
Inches.	*Feet.*	*Inches.*	*Inches.*	*Feet per minute.*	*Pounds.*	
9 by 10	Main, 2,250 Trip, 5,340	1⅛ ⅝	48 by 103 high, 175-pound working pressure.	Main, 400 Trip, 470	18,000	$2,200
9 by 10¼	Main, 2,950 Trip, 5,300	1 ⅝	54 by 106 high		19,500	2,000
9¼ by 10	Main, 2,150 Trip, 5,340	1⅛ ⅝	54 by 125 high, 175-pound working pressure.	Main, 350 Trip, 470	20,500	2,360
9½ by 10	Main, 2,900 Trip, 6,500	1⅛ ⅝	56 by 124 high, 200-pound working pressure.	Main, 400 Trip, 500	26,000	2,725
10 by 11	Main, 3,000 Trip, 6,900	1⅛ ⅝	60 by 126 high	Main, 422	28,000	2,800
10 by 12	Main, 3,150 Trip, 7,550	1⅛ ⅝	54 by 125 high, 175-pound working pressure.	Main, 357 Trip, 445	27,000	3,130
10 by 12	Main, 4,000 Trip, 10,000	1⅛ ⅝	66 by 120 high	Main, 430 Trip, 560	32,000	4,000
10 by 13	Main, 4,000 Trip, 8,200	1⅛ ⅝	66 by 125 high	Main, 380 Trip, 513	34,200	3,420
10 by 15	Main, 3,750 Main, 4,660 Trip, 10,100	1¼ 1⅛ ⅝	68 by 147 high	Main, 400 Trip, 490	32,500	3,780
10¼ by 12	Main, 2,800 Trip, 7,550	1⅛ ⅝	60 by 135 high, 200-pound working pressure.	Main, 377 Trip, 455	31,500	3,400
10¼ by 12	Main, 2,100 Trip, 3,700	1¼ ⅝	60 by 135 high, 200-pound working pressure.	Main, 390 Trip, 595	32,000	3,410
11 by 12	Main, 3,700 Trip, 8,250	1⅛ ⅝	62 by 132 high, 200-pound working pressure.	Main, 430 Trip, 625	36,500	3,550
11 by 13	Main, 4,080 Main, 5,380 Trip, 10,600	1¼ 1⅛ ⅝	68 by 147 high, 200-pound working pressure.	Main, 430 Trip, 500	40,000	4,410
11 by 13	Main, 5,500 Main, 4,500 Trip, 8,500	1⅛ 1¼ ⅝	66 by 125 high	Main, 395 Trip, 550	37,000	3,700
11 by 13	Main, 3,100 Trip, 6,400	1¼ ⅝	68 by 144 high, 200-pound working pressure.	Main, 435 Trip, 600	40,000	4,250
11 by 14	Main, 5,900 Trip, 11,300	1⅛ ⅝	66 by 120 high	Lower, 460 Trip, 520	37,000	4,300
12 by 12	Main, 3,000 Trip, 7,000	1¼ ⅝	72 by 120 high	Main, 465 Trip, 825	40,000	4,500
12 by 12	Main, 4,070 Main, 5,400 Trip, 9,850	1¼ 1⅛ ⅝	68 by 147 high, 200-pound working pressure.	Main, 445 Trip, 496	42,000	4,725
12 by 13	Main, 4,070 Main, 5,400 Trip, 9,850	1¼ 1⅛ ⅝	68 by 147 high, 200-pound working pressure.	Main, 445 Trip, 496	45,000	5,200
13 by 13	Main, 6,500 Trip, 14,400	1⅛ ⅝	74 by 144 high, 200-pound working pressure.	Main, 565 Trip, 735	50,000	5,250
12 by 14	Main, 4,380 Main, 5,100 Trip, 13,850	1⅜ 1¼ ⅝	72 by 147 high, 200-pound working pressure.	Main, 452 Trip, 567	51,000	5,250
12 by 14	Main, 6,900 Trip, 10,500	1¼ ⅝		Main, 420 Trip, 530	50,000	5,000
12 by 14	Main, 3,300 Trip, 7,400	1¼ ⅝	68 by 144 high, 200-pound working pressure.	Main, 558 Trip, 605	42,000	4,795
13 by 14	Main, 6,500 Main, 8,000 Trip, 12,800	1¼ 1⅛ ⅝		Main, 500 Trip, 550	43,000	5,000
14 by 14	Main, 8,100 Trip, 21,400	1¼ ⅝			60,000	6,000
14 by 15	Main, 8,500 Trip, 21,500	1¼ ⅝	80 by 153 high, 200-pound working pressure.	Main, 630 Trip, 885	65,000	6,500

Logging engine repair parts and materials.—All operators find it desirable to carry in stock a few duplicates of the small parts of logging engines that are most likely to fail. The fixed investment in such parts varies with the ideas of the management and the distance the operation is from points where repair parts can be purchased. For the purpose of a timber appraisal, the capital invested in this way may be placed at $100 per yarding engine.

Logging engine sleds.—For protection and convenience in moving, logging engines are mounted on well constructed sleds (Fig. 14). The more rigid and well secured such a sled is, the more aid it is in preserving the alignment and durability of parts. Sleds are equipped with heavy rings, chains, bolts, etc., for moving, snubbing, etc. They vary in length, ranging from 30 to 60 feet for both yarding and roading engines.

The total cost of these sleds ranges from $300 to $600. One 60-foot sled cost $600, $309 of which was expended for labor. It is estimated that 15,000 feet of No. 1 logs and 1 ton of iron were used in its construction. The runners were hewn on three sides. The total cost of building a 42-foot sled amounted to $293. This sled contained 11,000 feet of No. 1 logs, which were valued at $114. The labor cost of building three 40-foot sleds amounted to $612, which is at the rate of $204 per sled.

The life of sleds varies with the character of the sled and of the country, the way moving is accomplished, and the size of the machine. As a general thing it ranges between three and four years.

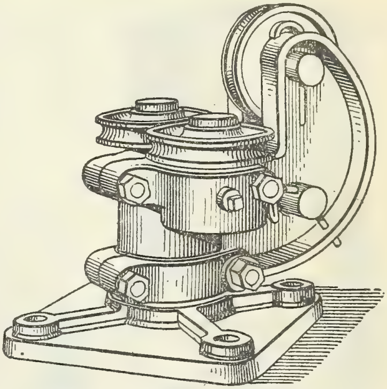

FIG. 31.—Trip line fair-leader.

Fair-leaders.—In the case of narrow drum yarding engines, where a true lead is necessary on the drums, one main line and one trip line fair-leader are mounted on the front end of the logging engine sled. They are made in a number of different designs. Figure 21 shows a main line fair-leader which is adapted for extra heavy service. It weighs 1,220 pounds and is sold for $100. Figure 31 shows a trip line fair-leader which is adapted for a $\frac{5}{8}$-inch line. It weighs 246 pounds and costs $50. A larger fair-leader of this type may be used for the main line. One adapted for 1-inch or $1\frac{1}{8}$-inch line weighs 675 pounds and costs $100.

Spark arresters.—In the States of Oregon and Washington the use of spark arresters under certain conditions is compulsory from June 1 to October 1, the Oregon law, which is substantially the same as that of Washington, reading:

> From June 1 to October 1 of each year it shall be unlawful for any person, firm, or corporation, or employee thereof, to use or operate any locomotive, logging engine, portable engine, traction engine, or stationary engine using fuel

other than oil, in or near forest or brush land. which is not provided with an adequate spark arrester kept in constant use and repair. Any person, firm, or corporation who shall willfully fail to comply with the foregoing provisions of this section shall be guilty of a misdemeanor, and upon conviction thereof shall pay a fine for each engine or locomotive without such spark arrester of not less than twenty-five dollars ($25.00) nor more than one hundred dollars ($100.00), and shall be enjoined from further use of such engine or locomotive until such spark arrester is provided. Escape of fire from an engine shall be prima facie evidence that such appliance has not been adequately maintained in compliance with this section. Under proof that any prosecution has been instituted under this section by any fire warden, any court of competent jurisdiction shall enjoin the further use of the engine involved, unless equipped and maintained in compliance with this section to the satisfaction of said fire warden, until the defendant has been acquitted of the charge preferred.

There are a number of different types of spark arresters used. The prices vary with the type of arrester and the size of the engine stack. What is claimed to be a particularly effective arrester can be purchased for from $125 to $160. Prices in general range from $20 to $160.

Extended fire boxes.—Manufacturers of logging engines are prepared to equip all logging engines having cylinders 10 inches or larger in diameter with extended fire boxes (fig. 32) at a cost of about $250.

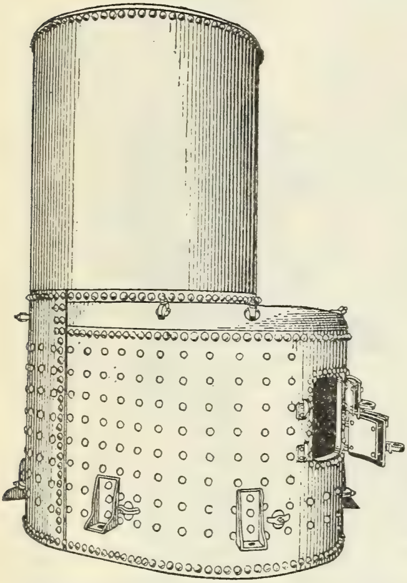

FIG. 32—Extended fire-box type of boiler.

Logging-engine water tanks.—As a rule, either wooden or steel water tanks are mounted on the rear end of each logging-engine sled (fig. 14). The steel tanks, which fit on a saddle, give the best service and cost from $100 to $200, depending on their capacity. A 5 by 8 foot steel tank costs about $125. This tank is sometimes made in two compartments; one for oil, the other for water.

Straw drums.—The drum used to operate the straw line may be located on an extension of the main or trip drum shaft, or on the main drum shaft inside the frame. The cost of equipping an engine with a straw drum amounts to about $150.

Loading drums.—When separate engines are not used for loading purposes, it is necessary to have a third friction drum on the yarding engines. On compound-geared yarding engines this drum is located on the main drum shaft, either on the inside or outside of the frame.

On tandem-drum engines the most convenient location is on an extension of the main drum shaft. It is a narrow drum of relatively large diameter, which, having its own friction and brake, can be operated independently of the main drum. The cost of equipping an engine with this device amounts to about $150.

Oil-burner equipment.—The approximate cost of full equipment for burning crude oil on yarding and roading engines and skidders is about $450 for each machine; on loading engines, about $375. These prices include the tank on the sled, which is used for the storage of both oil and water. The cost of maintenance of this equipment is about $25 per year.

The oil is hauled from the storage tank to the tank on the rear end of the sled in tank cars, which have a capacity of about 7,000 gallons, and cost about $1,000.

A large steel storage tank is erected at a convenient point on the logging railroad to receive oil in bulk. The cost of a 200,000-gallon steel storage tank, together with an 8-inch pipe and valves for filling, amounts to about $4,000.

Electric signals.—Until very recently signals were universally given by means of a light wire attached to the whistle lever, the wire, either solid or twisted, being strung taut along the outer edge of the run from the engine to the rear of the chance. A solid signal wire costs about $3; a twisted one, about $10.

A large number of operators now use an electrical device which is connected with the lever of the whistle. The current is carried to the woods' end through insulated wires, which can be laid upon the ground or carried upon supports, as desired. Relays of push buttons along the line make it possible to give the signals at any point. Power to operate the whistle is furnished by from 6 to 12 dry batteries. The signal itself is the same as with the old method, and can be heard by the yarding crew, who thus know that the proper signal has been given to the engineer. The device eliminates the trouble of keeping a taut signal wire. It is claimed that the signals are transmitted more promptly than by the old method. One manager who is using the electric signal and who has a reputation for conservatism considers the device a "safety-first" appliance. Undoubtedly it will be universally used in the near future. The device complete for a yarding engine costs about $100.

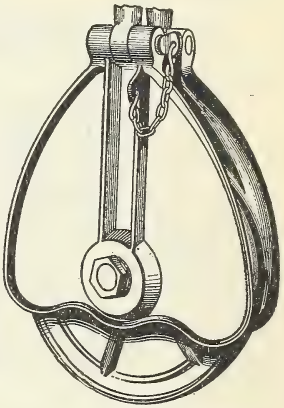
FIG. 33.—Moving block.

Blocks.—Figures 19, 20, 22, 27, and 33 indicate the types of blocks used in general yarding. A number of companies manufacture blocks, so that there is a large assortment for operators to select from.

Blocks of as large size as possible should be used. Wire-rope manufacturers recommend blocks with much larger sheaves than are practical in the woods. For 1-inch lines sheaves should not be less than 12 inches in diameter; and for $1\frac{1}{8}$ to $1\frac{1}{4}$ inch lines, from 14 to 18 inches. The standardization committee of the Pacific Logging Congress in 1913 recommended that blocks having sheaves of the following sizes be adopted:

Trip-line blocks:

9 by $1\frac{1}{4}$ by $1\frac{15}{16}$ inches, hub length 3 inches, grooved for a $\frac{5}{8}$-inch line.
12 by $1\frac{1}{4}$ by $1\frac{15}{16}$ inches, hub length 3 inches, grooved for a $\frac{3}{4}$-inch line.
14 by $1\frac{1}{2}$ by $2\frac{7}{16}$ inches, hub length 3 inches, grooved for a $\frac{3}{4}$-inch line.
18 by $1\frac{1}{2}$ by $2\frac{7}{16}$ inches, hub length 4 inches, grooved for a $\frac{3}{4}$-inch line.
24 by 2 by $3\frac{7}{16}$ inches, hub length 5 inches, grooved for a $\frac{3}{4}$-inch line.

Yarding blocks:

10 by 2 by $2\frac{1}{2}$ inches, hub length 3 inches, grooved for a $1\frac{1}{4}$-inch line.
12 by $2\frac{1}{2}$ by $2\frac{15}{16}$ inches, hub length $3\frac{1}{2}$ inches, grooved for a $1\frac{1}{2}$-inch line.

Butt-chain blocks:

16 by 8 by $3\frac{7}{16}$ inches, hub length 8 inches, if grooved for a $1\frac{1}{2}$-inch line.
20 by 8 by $3\frac{7}{16}$ inches, hub length 8 inches, if grooved for a $1\frac{1}{2}$-inch line.
24 by 8 by $3\frac{7}{16}$ inches, hub length 8 inches, if grooved for a $1\frac{1}{2}$-inch line.

The cost of blocks varies because of differences in the type, size, and make and because different material is used in their construction. The following tabulations give the type, size, and weight of blocks that are more or less standard, also the selling prices f. o. b. Portland in March, 1916. The material used in the construction of these blocks is indicated in the list of extra parts.

Butt-chain lead blocks (Fig. 25).

No.	Sheave.	Shaft.	Bearing.	Weight.	Net price.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	
1	24 by 8	$3\frac{1}{2}$	10	820	$128.00
2	20 by 7	$3\frac{1}{2}$	10	650	102.00
3	16 by 7	3	10	475	72.00

Extra parts.

Items.	Net price.		
	No. 1.	No. 2.	No. 3.
Tool-steel shackle	$18.80	$17.20	$15.25
Pair steel block sides	44.00	34.00	24.00
Casehardened steel center shaft	6.00	6.00	6.00
Oil cup and nut with lock washer	1.40	1.40	1.40
Half nut with lock washer	.60	.60	.60
Bronze bushing	7.60	7.60	7.60
Manganese-steel sheave, bronze bushed	50.00	38.00	28.00

Moving blocks (Fig. 35).

No.	Sheave.	Pin.	Weight.	Net price.
	Inches.	*Inches.*	*Pounds.*	
1	14 by 3	3	230	$45.00
2	16 by 3	3	270	49.00

Extra parts.

Items.	Net price.	
	No. 1.	No. 2.
Tool-steel shackle	$3.60	$3.60
Pair steel block sides	22.00	24.00
Casehardened steel pin	3.60	3.60
Half nut with lock washer	.65	.65
Bronze bushing	2.70	2.70
Manganese-steel sheave, bronze bushed	16.65	20.00

Yarding blocks (Fig. 30).

No.	Sheave.	Pin.	Diameter.	Weight.	Net price.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	
1	10 by 2½	2½	3	110	$22.80
2	12 by 2½	2½	3	145	26.80

Extra parts.

Items.	Net price.	
	No. 1.	No. 2.
Tool-steel shackle	$2.80	$2.80
Pair steel block sides	7.60	7.60
Casehardened steel pin	2.80	9.60
Half nut and lock washer	.40	.40
Bronze bushing	1.80	1.80
Manganese-steel sheave, bronze bushed	8.80	11.20

Trip-line side or corner block (Fig. 23).

No.	Size.	Pin.	Hub.	Weight.	Net price.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	
1	9 by 1¼	1½	2¼	40	$8.80
2	12 by 1¼	2	3	55	12.00

Extra parts.

Items.	Net price.	
	No. 1.	No. 2.
Patent combination shackle with guard	$0.60	$0.80
Pair steel block sides	4.00	6.00
Casehardened steel pin	.80	1.80
Oil cup and nut with lock washer	.40	.45
Half nut with lock washer	.15	.25
Bronze bushing	.80	1.60
Manganese-steel sheave, bronze bushed	3.40	6.40

Trip-line head blocks (Fig. 22).

No.	Sheave.	Pin.	Hub.	Weight.	Net price.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	
1	14 by 1½	2½	3	95	$17.60
2	18 by 1⅝	2½	4	140	26.00
3	24 by 2	3	5	235	44.00

Extra parts.

Items.	Net price.		
	No. 1.	No. 2.	No. 3.
Forged-steel shackle[1]	$1.20	$1.60	$2.80
Pair steel block sides	7.20	9.60	18.80
Casehardened steel pin	2.00	2.60	3.20
Oil cup and nut with lock washer	.60	.60	1.40
Half nut with lock washer	.40	.45	.60
Bronze bushing	1.60	2.00	3.60
Manganese-steel sheave, bronze bushed	7.60	12.20	20.00

[1] No. 3 has tool-steel forged shackle.

Table 11 gives the fixed investment in ground yarding blocks for one yarding engine. To allow for a proper range, the total cost and weight, including blocks of different sizes, is shown in three cases. The aim is to include a liberal amount of such equipment, taking into account the fact that the number of blocks needed for different yarding chances varies and that some blocks are undergoing repairs at times. This table can be easily modified to take care of a given set of conditions.

TABLE 11.—*Fixed investment in blocks for one yarding engine.*

Number.	Items.	Case 1.			Case 2.			Case 3.		
		Size.	Weight (pounds).	Net price.	Size.	Weight (pound).	Net price.	Size.	Weight (pound).	Net price.[1]
2	Butt chain blocks	24 by 8	1,640	$256.00	20 by 7	1,300	$204.00	16 by 7	950	$144.00
2	Moving blocks	16 by 3	540	99.00	14 by 3	460	90.00	14 by 3	460	90.00
2	Yarding blocks	12 by 2½	290	53.60	10 by 2½	220	45.60	10 by 2½	220	45.60
1	Head trip block	24 by 2	235	44.00	18 by 1⅝	140	26.00	14 by 1½	95	17.60
1	Corner or side block	14 by 1½	96	17.60	14 by 1½	95	17.60	14 by 1½	95	17.60
8	Side blocks	12 by 1¼	440	96.00	12 by 1¼	440	96.00	12 by 1¼	440	96.00
	Extra parts	....	400	100.00	....	300	75.00	....	250	50.00
16	Total	....	3,640	666.00	....	2,955	554.00	....	2,510	460.00

[1] Prices are those of March, 1916.

Yarding rollers.—Figure 28 shows a yarding or stump roller. The use of such rollers in connection with ground yarding is discussed on page 72. The method is also shown in figure 15. They weigh from 210 to 325 pounds and cost from $45 to $60.

Ground yarding lines.—Ground yarding lines are all made of wire rope, without which modern methods of logging could not have developed. Wire rope consists of a group of strands laid symmetrically around a center core, the strands consisting of wires twisted together symmetrically according to a definite geometrical arrangement. The unit of construction is the strand. While a large number of geometrical combinations are possible, the ordinary practice is to use 1 wire in the center of the strand and to surround it with 6 wires, then sucessively with layers of 12, 18, 24, and 36 wires, etc., the construction being known as the concentric strand. Six wires around a center wire produce a strand for a haulage rope. A supplementary layer of 12 wires makes a 19-wire strand for a hoisting rope. This strand in turn, when covered by a third layer of 18 wires, makes a 37-wire strand that is used in a special flexible hoisting rope. In strands of uniform diameter the greater the number of wires in the strand the more flexible the rope. The strands, usually 6 in number, are, as a rule, laid together around a hemp center.

The "haulage rope," 6 strands of 7 wires each, is a relatively stiff rope with large wires capable of resisting external wear. Its use is limited to conditions where there is much abrasion and little bending around sheaves. In the "hoisting rope," 6 strands of 19 wires each, the wires are smaller than those in a 6 by 7 rope, and are less able to resist abrasion, but can more easily be bent around sheaves and drums. The "special pliable rope," 6 strands of 37 wires each, is composed of still smaller wires than the 6 by 19, possesses greater flexibility, and may be bent around fairly small sheaves. It should not be subjected to much external wear, particularly in the smaller sizes, as the wires will be worn off quickly. The "extra pliable rope," 8 strands of 19 wires each, is more flexible than the 6 by 19, and may be used over smaller sheaves than the latter. It is about as flexible as 6 by 37 construction, but not so strong, owing to its larger hemp center.

The ropes so far referred to are of the one-size-wire construction. In the making of 6 by 19 rope certain features result from a slight modification of the strands and wires. In Seale construction the center wire of the strand is large, the next layer of 9 wires is small, and the outer layer of 9 wires large. These strands produce a rope somewhat stiffer than ordinary 6 by 19 construction and having a limited number of uses. The strands of another construction consist of wires of three different sizes, 7 inside wires of uniform diameter surrounded by 12 wires which are alternately large and small. This combination increases the metallic area and strength by approximately 10 per cent.

There are two general methods of laying up rope—the common type, known as regular lay, and Lang's lay. In the former the wires are twisted in one direction and the strands are laid into the rope in the opposite direction. Most of the rope made in America is made in this manner, and it has become standard for general work. In the latter, the wires in the strand and the strands in the ropes are twisted in the same direction.

Wire ropes are made almost exclusively from iron or steel, and the materials used may be further grouped into three main divisions, viz, iron, crucible cast steel, and plow steel. The wire rope used for yarding lines is for the most part made from plow steel and special plow steel. These two classes of rope, besides being used for main, trip, and straw lines, are used for chokers and overhead yarding lines, the special plow steel being especially adapted for overhead work. For lines other than chokers a 6 by 19 construction with a hemp core is used. A small percentage of operators make their main yarding lines from rope that has a steel core.

The diameter and length of lines is discussed under the heading "Wire rope cost."

The selling price of wire rope, besides varying with the grade and type of construction, fluctuates with economic conditions. The list prices of manufacturers for the same grade and construction are the same. On March 8, 1916, the discount quoted by one wire-rope agent was 37½ per cent off the list prices. About two years ago the discount was about 60 per cent. Under normal conditions the discount is about 50 per cent.

The following tables give the net prices on wire rope of the grade and type of construction ordinarily used in logging operations. The prices are based on a discount of 50 per cent off the list. The strengths given are standard, being those adopted by the manufacturers on May 1, 1910.

TABLE 12.—*Standard plow steel hoisting rope.*

[6 strands, 19 wires to the strand, 1 hemp core.]

Net price per foot.	Diameter in inches.	Approximate weight per foot in pounds.	Approximate strength in tons of 2,000 pounds.	Proper working load in tons of 2,000 pounds.
$0.06	¼	0.10	2.65	0.53
.06025	5/16	.15	3.8	.76
.0625	⅜	.22	5.75	1.15
.065	7/16	.30	8	1.6
.07	½	.39	10	2
.08	9/16	.50	12.3	2.4
.095	⅝	.62	15.5	3.1
.13	¾	.89	23	4.6
.17	⅞	1.20	29	5.8
.215	1	1.58	38	7.6
.27	1⅛	2	47	9.4
.325	1¼	2.45	58	12
.395	1⅜	3	72	14
.465	1½	3.55	82	16
.54	1⅝	4.15	94	19
.65	1¾	4.85	112	22
.73	1⅞	5.55	127	25
.79	2	6.3	140	28

NOTE.—The net prices given are based on a discount of 50 per cent off the list prices. Add 10 per cent to the list prices for wire center.

TABLE 13.—*Special plow steel hoisting rope.*

[6 strands, 19 wires to the strand, 1 hemp core.]

Net price per foot.	Diameter in inches.	Approximate weight per foot in pounds.	Approximate strength in tons of 2,000 pounds.	Proper working load in tons of 2,000 pounds.
$0.065	$\frac{1}{4}$	0.10	3.15	0.63
.065	$\frac{5}{16}$	.15	4.50	.9
.0725	$\frac{3}{8}$	.22	6.75	1.35
.0775	$\frac{7}{16}$	.30	9.4	1.9
.085	$\frac{1}{2}$	.39	12.1	2.4
.095	$\frac{9}{16}$	.50	14.5	2.9
.1125	$\frac{5}{8}$	.62	19	3.8
.155	$\frac{3}{4}$	.89	26.3	5.3
.195	$\frac{7}{8}$	1.20	35	7
.25	1	1.58	45	9
.31	$1\frac{1}{8}$	2	56	11
.375	$1\frac{1}{4}$	2.45	69	14
.45	$1\frac{3}{8}$	3	84	17
.55	$1\frac{1}{2}$	3.55	98	20
.65	$1\frac{5}{8}$	4.15	110	22
.80	$1\frac{3}{4}$	4.85	133	27
.875	$1\frac{7}{8}$	5.55	150	30
.925	2	6.30	166	33

NOTE.—The net prices given are based on a discount of 50 per cent off the list prices. Add 10 per cent to the list prices for wire center.

TABLE 14.—*Extra pliable plow steel hoisting rope.*

[8 strands, 19 wires to the strand, 1 hemp core.]

Net price per foot.	Diameter in inches.	Approximate weight per foot in pounds.	Approximate strength in tons of 2,000 pounds.	Proper working load in tons of 2,000 pounds.
$0.06625	$\frac{1}{4}$	0.09	2.25	0.45
.0675	$\frac{5}{16}$	.13	3.35	.67
.07	$\frac{3}{8}$	.20	5.12	1.02
.075	$\frac{7}{16}$	.27	6.90	1.38
.08	$\frac{1}{2}$	.35	8.70	1.74
.09	$\frac{9}{16}$	.45	11.60	2.32
.105	$\frac{5}{8}$	.56	14	2.8
.145	$\frac{3}{4}$	.80	20	4
.19	$\frac{7}{8}$	1.08	26	5.2
.24	1	1.42	33	6.6
.30	$1\frac{1}{8}$	1.80	43	8.6
.36	$1\frac{1}{4}$	2.20	52	10.4
.435	$1\frac{3}{8}$	2.70	64	12.8
.515	$1\frac{1}{2}$	3.19	74	14.8

NOTE.—The net prices given are based on a discount of 50 per cent off the list prices.

Table 15 indicates the fixed investment in ground yarding lines. To take care of different conditions, the total cost and weight is given for 24 cases, which include lines of different lengths, diameters, and grades.

TABLE 15.—*Fixed investment in ground yarding lines.*

Type of line.	Length.	6 by 19 plow steel.									6 by 19 special plow steel.								
		Diameter.	Weight.	Cost.	Diameter.	Weight.	Cost.	Diameter.	Weight.	Cost.	Diameter.	Weight.	Cost.	Diameter.	Weight.	Cost.	Diameter.	Weight.	Cost.
	Feet.	*Inches.*	*Pounds.*		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Main	800	1¼	1,960	$260	1⅜	2,400	$316	1½	2,840	$372	1¼	1,960	$300	1⅜	2,400	$360	1½	2,840	$440
Trip	2,000	9/16	1,000	160	⅝	1,240	190	¾	1,780	260	9/16	1,000	190	⅝	1,240	225	¾	1,780	310
Straw	2,000	⅜	440	135	⅜	440	135	⅜	440	135	⅜	440	145	⅜	440	145	⅜	440	145
Straps	....	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43
Total	....	....	3,716	598	....	4,396	684	....	5,376	810	....	3,716	678	....	4,396	773	....	5,376	938
Main	1,000	1¼	2,450	325	1⅜	3,000	395	1½	3,550	465	1¼	2,450	375	1⅜	3,000	450	1½	3,550	550
Trip	2,500	9/16	1,250	200	⅝	1,550	238	¾	2,225	325	9/16	1,250	238	⅝	1,550	281	¾	2,225	387
Straw	2,500	⅜	550	156	⅜	440	156	⅜	440	156	⅜	550	181	⅜	440	181	⅜	440	181
Straps	....	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43
Total	....	....	4,566	724	....	5,306	832	....	6,531	989	....	4,566	837	....	5,306	955	....	6,531	1,161
Main	1,200	1¼	2,740	390	1⅜	3,600	474	1½	4,260	558	1¼	2,740	450	1⅜	3,600	540	1½	4,260	560
Trip	3,000	9/16	1,500	240	⅝	1,860	285	¾	2,670	390	9/16	1,500	285	⅝	1,860	337	¾	2,670	465
Straw	3,000	⅜	660	187	⅜	440	187	⅜	440	187	⅜	660	217	⅜	440	217	⅜	440	217
Straps	....	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43
Total	....	....	5,216	860	....	6,216	989	....	7,686	1,178	....	5,216	995	....	6,216	1,137	....	7,686	1,285
Main	1,400	1¼	3,430	455	1⅜	4,200	553	1⅜	4,970	651	1¼	3,430	525	1⅜	4,200	630	1½	4,970	770
Trip	3,500	9/16	1,750	280	⅝	2,170	333	¾	3,115	455	9/16	1,750	333	⅝	2,170	394	¾	3,115	542
Straw	3,500	⅜	770	219	⅜	440	219	⅜	440	219	⅜	770	254	⅜	440	254	⅜	440	254
Straps	....	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43	....	316	43
Total	....	....	6,266	997	....	7,126	1,148	....	8,841	1,368	....	6,266	1,155	....	7,126	1,321	....	8,841	1,609

NOTE.—Cost of lines is based on a net price for wire rope of 50 per cent off the list price.

Butt chains and butt hooks.—A butt chain or line (fig. 23) is a short connection by which the chokers are attached to the main yarding line. It consists of the main connecting link, either a heavy steel chain with short links or a wire rope with eyes spliced in each end, with a hook or clevis on the end which is attached to the main line and a swivel, a link, and a butt hook on the other. The swivel in the connection allows the log to roll when being pulled in without twisting the main line. Butt chains are made in different weights, depending upon the personal ideas of the operator and the conditions of the chance. They range from 5 to 8 feet in length. Where they are constructed of wire rope, sockets instead of splices may be used.

Besides the plain heavy butt hook there are a number of patented ones which are so constructed that the socket on the choker is locked in place and can not come out, as often happens with open hooks. This is an advantage which well repays for the extra cost.

Although not actually a part of the butt chain, the trip-line connection is usually considered as a part. It is attached to the same clevis as the butt chain by means of a link, a swivel, and another clevis. A hook may be used instead of a second clevis.

A butt chain without the hook costs about $13 and weighs about 128 pounds. Tag lines are considerably lighter. Butt hooks ordinarily used cost from $6 to $15. Clevises cost from $2.50 to $3.50. Figure 26 shows one type of rigging plate which is used where two butt chains are used on connection with tag lines. This plate without clevises costs about $4. The fixed investment in butt chains, butt hooks, and clevises used in connection with one yarding engine amounts to about $100.

Chokers.—A choker (figs. 24 and 25) is a piece of wire rope which may be set on a log in such a way as to form a noose. There are two distinct forms, the flat-hook choker and the type with the hook running loose on the line. The flat-hook type consists of a piece of wire rope with an eye in one end and a flat hook attached to the other. The line is passed around the log and the flat hook is hooked over the line, making a noose. The other type consists of a piece of wire rope with eyes spliced in each end and a hook which runs loose on the line. The hook is slid along until it will hook into the end of the line, thus forming a noose. On rough ground this type does not come loose so quickly as the flat hook. The flat hook is easier to handle. The flat hook works better in high-lead yarding than in ground yarding, the tension on the line being more even. Forged-steel sockets are used to a great extent on the ends of the choker instead of spliced eyes, as they save time and some feet of line and are more durable. There are many styles of both flat and running hooks used.

The length of a choker depends on the size of the timber; the range is from 15 to 30 feet or more. When chokers are made from new rope, 8 by 19 construction is generally used, the diameter of the rope ranging from 1⅛ to 1⅜ inches. Most chokers are made of 1¼-inch rope. Choker hooks for 1⅛ to 1¼ inch line cost from $2.50 to $10. The type shown in figure 24 costs about $2.50 each. Sockets for 1⅛ and 1¼ inch line cost about $2.25 each. On this basis a 30-foot 1¼-inch choker, with choker hook, costs about $23 and weighs about 70 pounds.

The number of chokers in a set, or used in connection with one yarding engine, should vary with the character of the chance and the material from which they are made. For the purpose of this discussion eight chokers will be considered ample. It has been estimated that a 30-foot 1¼-inch choker, with sockets and hook, costs about $23. The chokers in a set are not of uniform length, however, and a 30-foot choker is longer than the average. For the purpose of estimating the fixed investment in chokers and choker hooks necessary for one yarding engine, an average length of 25 feet is assumed. On this basis the fixed investment amounts to about $165.

Woods water system.—Two methods of supplying water for logging engines are used. The more common one is to convey the water to the engines in pipes; the other, in tank cars. Where water is plentiful it may be possible to supply all the engines through pipes by gravity at slight expense. Where the water is less plentiful it may be advisable to pump all the water used in the camp, in some cases by a central pumping station. Some operators haul the water in tank cars. At one three-side camp the water system, consisting of two steam pumps with boilers and 6 miles of pipe, cost $4.000. It would seem that a camp water system should never cost more than this. The selling price of black pipe is approximately as follows:

	Per 100 feet.
¾-inch pipe	$4.15
1¼-inch pipe	6.10
1½-inch pipe	7.30

Miscellaneous equipment.—In addition to the equipment listed above, a rather large amount of small equipment is necessary, such as splicing tools, saws, axes, sledges, wedges, clamps, swamp hooks, oil cans, wrenches, shovels, hoes, etc. The fixed investment in such equipment amounts to about $250 per engine where one engine is operated; about $200 where more than one engine is operated. These amounts are intended to take care of the equipment in use as well as the stock on hand.

INVESTMENT IN EQUIPMENT.

The following is a summary of the investment in yarding equipment in connection with one yarding engine in three cases. The cost does not include freight.

Summary of equipment for one yarding engine.

CASE 1.

Equipment.	Cost.
10 by 11 inch standard compound-geared yarding engine	$3, 350
Repair parts and materials for yarding engine[1]	100
Yarding engine sled	350
Fair-leaders	150
Extended fire box	250
Straw drum	150
Electric signals	100
Fuel-oil equipment and water tank	450
Blocks and extra parts	550
Yarding rollers	150
Ground yarding lines; 1,200 feet of $1\frac{1}{4}$-inch main line; 3,000 feet of $\frac{9}{16}$-inch trip line; and 3,000 feet of $\frac{3}{8}$-inch straw line	995
Butt chains, butt hooks, and clevises	70
Chokers and choker hooks	165
Miscellaneous equipment	225
Total cost	7, 055

NOTE.—Statement includes equipment in use and in stock.

CASE 2.

Equipment.	Cost.
11 by 13 inch standard compound-geared yarding engine	$4, 600
Repair parts and materials for yarding engine	210
Yarding engine sled	400
Fair-leaders	150
Extended fire box	250
Straw drum	150
Electric signal	100
Fuel-oil equipment and water tank	450
Blocks and extra parts	575
Yarding rollers	150
Ground yarding lines: 1,000 feet of $1\frac{3}{8}$-inch main line; 2,500 feet of $\frac{5}{8}$-inch trip line; and 2,500 feet of $\frac{3}{8}$-inch straw line	955
Butt chains, butt hooks, and clevises	70
Chokers and choker hooks	175
Miscellaneous equipment	250
Total cost	8, 485

NOTE.—Statement includes equipment in use and in stock.

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[1] Every operator finds it necessary to carry certain repair parts and materials in stock. While the value of these parts varies, it is thought that the amount given in the table is ample in most cases. One operator, employing 5 yarders, carried parts and materials in stock to the amount of $1,700. This stock was made up of an extra guide and crank pin, brasses, valve stems, a steam gauge, gauge glasses, an extra cylinder head, a supply of valves for vulnerable parts of the engine, a small but complete set of pipe fittings and valves for water system, packing, etc.

CASE 3.

Equipment.	Cost.
12 by 14 inch standard compound-geared yarding engine	$5,000
Repair parts and materials for yarding engine	220
Yarding engine sled	450
Fair-leaders	150
Extended fire box	250
Straw drum	150
Electric signal	100
Fuel-oil equipment and water tank	450
Blocks and extra parts	675
Yarding rollers	150
Ground yarding lines: 1,000 feet of 1½-inch main line; 2,500 feet of ¾-inch trip line; and 2,500 feet of ⅜-inch straw line	1,161
Butt chains, butt hooks, and clevises	70
Chokers and choker hooks	185
Miscellaneous equipment	275
Total cost	9,286

NOTE.—Statement includes equipment in use and in stock.

COST.

Output.—Taking it straight through by camps, good and bad country, the ground yarding output, naturally the basic element in a cost computation, ranges between 40,000 and 80,000 feet per yarding engine per yarding day of 10 hours. A few camps average a little less than 40,000 feet, others average more than 80,000. For a short period the output may be considerably lower or higher. The largest volume of timber ever yarded in a day of 10 hours in this region amounted to 432,000 feet. The crew, on its mettle, was working in ideal natural conditions and with first-class equipment. A crew working in a particularly hard chance may get as little as 100,000 feet in one week; in a particularly good chance, as much as 1,000,000 feet in the same time.

The estimating of the average output in a given chance or set of conditions is extremely difficult and liable to error. It has been estimated that a yarding engine carrying 900 feet of line should average 45 logs, or from 67,500 to 90,000 feet per day in timber where the logs average from 1,500 to 2,000 feet to the log; 50 logs, or from 50,000 to 75,000 feet per day in timber where the logs average from 1,000 to 1,500 feet; 55 logs, or from 27,500 to 55,000 feet per day in timber where the logs average from 500 to 1,000 feet; and 65 logs, or about 30,000 feet per day in timber where the logs average less than 500 feet. These estimates were based on time records. One hour each day was allowed for moving yarding engines; four for the placing of chokers, unfastening of logs by the chaser, removing unmerchantable timber from the roads, hauling wood logs, changing lines, etc.;

two and one-half hours for the starts and stops to straighten the logs out in the roads; two and one-half hours hauling the main line in and out. Average ground conditions were assumed.

It is obvious that estimates made in this way are artificial and of questionable value. Yarding records can be found which indicate that the above estimates are in error. In fact, the man who made this estimate has since exceeded it in small timber.

Without doubt, experience of the right character is the best basis for estimating the yarding output with specific conditions. One can acquire a satisfactory basis for estimating yarding output through observation, including a careful examination of the different factors of each chance, together with an analysis of output records. In the following discussion of the labor cost, a body of such records is given, with the factors in the case stated as fully and accurately as possible.

Labor cost.—As a rule it is the labor cost only that is given under the heading "Yarding cost" in the logging cost statements of operators, for the labor constitutes the bulk of the yarding cost, though by no means all of it. Cost is largely determined by output, but the size of the crew and the wages paid also count.

Statements giving the average labor cost per thousand feet, because they vary so much and because it is so difficult to relate average costs to practical assumptions, are of little value. The following statements may afford some clew to this cost, but should not be taken too seriously:

Labor cost per thousand feet (ground yarding).

Average logs:	
2,000 feet per log	$0.44
1,750 feet per log	.50
1,500 feet per log	.57
1,250 feet per log	.64
1,000 feet per log	.66
750 feet per log	.87
500 feet per log	1.15
250 feet per log	1.50

[Based on the assumption that the logs averaged 1,200 feet in volume.]

Stand per acre:	
20,000 to 40,000 feet	$0.64
40,000 to 60,000 feet	.60
60,000 to 80,000 feet	.57
80,000 to 100,000 feet	.54

The number of men in a yarding crew is more or less fixed, but it can not be said that there is a standard crew. Foremen have different ideas of the proper size of a crew, and the members of the amount of work they should do. In addition, the size of the crew varies to some extent in the same camp with the character of the chance; or the size of the timber, roughness and steepness of the ground, length of haul, amount of down timber, etc. When labor is scarce and hard to handle, operators not infrequently find it desirable to carry extra help in the rigging crew in order to provide for sudden vacancies.

The basis of employment and payment of labor in this region is a 10-hour day, with a charge for board. Hook tenders are sometimes paid by the month.

During certain years, or parts of years, wages are higher than in others. At a given time some camps pay 8 to 10 per cent more per day per man than others. In some camps some of the men, because of special fitness or length of service, receive a larger compensation than others for the same class of work. For these reasons it is difficult to give the average wages paid the different members of the yarding crew.

The following list is intended to approximate the wages—average, high, and low—paid the labor working in ground yarding crews by the logging companies in the region during the past six years:

Approximate wages of ground yarding crews.

Position.	Wages per day.		
	Average.	High.	Low.
Hooktenders	$5.25	$6.00	$4.50
Rigging slingers	3.50	3.75	3.25
Choker men	3.25	3.50	3.00
Chasers	3.25	3.50	3.00
Swampers	3.00	3.25	2.75
Snipers	3.00	3.25	2.75
Signalman	2.75	3.00	2.50
Engineer	3.50	3.75	3.25
Fireman	2.50	2.75	2.25
Wood buck	2.50	2.75	2.25

The wages given in the column headed "Low" are not the lowest wages that have been paid. Camps that have paid the wages included in the column headed "Average" paid the following wages in October, 1915:

	Per day.
Hook tenders	$3.50
Rigging slingers	2.75
Choker men	2.50
Chasers	2.50
Swampers	2.25
Snipers	2.25
Signalman	2.00
Engineer	3.00
Fireman	2.00
Wood buck	2.25

A few operators find it economical now and then to run a side by contract, in which case the operator may furnish everything except the labor; or he may furnish only the large equipment, the contractor furnishing the labor, supplies, etc.

A few camps use bonus or profit-sharing systems. As a rule, the system consists in setting a standard output and allowing all the members of the yarding crew, or certain members of the yarding crew who have been in the employ of the company a certain length of time, a certain amount per thousand feet in addition to their regular wages for every thousand feet yarded in excess of the standard. The regular wages may equal the wages the company would pay if they were not using a bonus system, or they may be less.

The company pays a bonus to only those men who are directly connected with the handling of the logs from the stump to the car, such as hook tenders, chasers, rigging slingers, and signalmen, eliminating such men as wood bucks, swampers, snipers, etc. Wages comparable with the wages paid in camps that are not using a bonus system are paid, regardless of whether the standard output is made or exceeded. Those members of the crew who are working under the bonus system are paid an additonal amount as bonus when the yarding output exceeds the standard output, as follows: For each 1,000 feet of daily average output above the standard the wages of the men are increased 1 per cent. The standard is set by the logging superintendent for each chance monthly, or as often as conditions require. In establishing the standards, it is the stated aim of the company to put them where they can be made by an average crew without undue effort.

It is unusual to find a camp where all the logs are yarded direct to the landing, as many operators find it necessary to do a little double hauling, others a great deal. For this reason it is difficult to secure specific costs for direct yarding. The following costs are given more for the purpose of illuminating the subject than to give exact knowledge:

(1) The labor cost of transporting the logs from the stump to the landing, practically all single hauling, at a camp along the Columbia River in 1912, amounted to $0.69 per thousand feet.

This cost includes a part of the wages of the camp foreman, one-half the wages of the timekeeper, and all the wages of the scaler. It does not include the cost of moving the yarders from one landing to another, the taking in and the setting of lines when moving, the grading of yarder settings, or any phase of the loading of the logs. The following men were employed:

	Wages per day.
Hook tender	$6.00
Rigging slinger	4.00
Rigging slinger	3.50
Rigging slinger	3.25
Sniper	3.00
Chaser	3.25–3.50
Signalman	2.50
Butt chain block tender	3.25
Fireman	2.75
Wood buck	2.50
Woodchopper	2.50
Engineer	4.00
Log brander	2.50

During a part of the year oil was burned in two of the three yarders, which reduced the crew of the oil-burning yarders by three men, viz, the fireman, wood buck, and woodchopper. The number and wages of the men, of course, varied some.

The yarding chances from the standpoint of the ground were for the most part as good as can be found in this region, the average maximum yarding distance amounting to about 800 feet. Seldom, if ever, was the ground steep enough to cause the logs to run. Not less than two logs were yarded at a turn, sometimes three or four, and occasionally as many as five.

The forest is about 150 years of age and is cutting about 80,000 feet per acre, the trees averaging about 28 inches in diameter at breast height. About 95 per cent of the stand is Douglas fir, the rest hemlock.

The yarders were 10 by 11 inch, compound-geared engines, up-to-date in design, in good repair, and were driven at practically their maximum speed.

Yarders Nos. 1 and 2 handled longer logs than yarders No. 3, which was due to different methods of marketing. Logs 90 feet or more in length were yarded by these two yarders, the average length amounting to 60 feet. The maximum lengths handled by yarder No. 3 were 40 feet, averaging about 36 feet.

The effect of handling long logs is shown in the following summary of the yarding output. It will be noted that the daily output of yarder No. 3, which handles short logs, was 15,000 feet less than that of yarder No. 2, and 17,000 feet less than yarder No. 1. While it can not be claimed that the difference in output was entirely due to differences in the log lengths, similarity in the logging chances, methods, equipment, and the like, suggest strongly that this is the reason. The three yarders were of the same size, make, and age. The chances from the standpoint of timber, ground, and yarding distances were practically the same, and the average daily outputs of yarders Nos. 1 and 2 were practically the same, both from the standpoint of volume and the number of logs.

TABLE 16.—*Summary of yarding output.*

Yarder.	Number of logs.	Number of machine days.	Total scale.	Average number of logs per day.	Average volume of logs.	Average daily output.
			Feet.		*Feet.*	*Feet.*
No. 1	27,912	253¼	19,664,124	118	705	83,679
No. 2	26,062	230½	18,789,422	113	721	81,692
No. 3	25,246	179	11,848,857	141	469	66,220
Total	79,220	662¾	50,302,403	372	620	231,591

	Feet.
Average length of logs	51
Average number of logs per yarder per day	119
Average output per yarder per day	77,197

(2) The labor cost of transporting the logs from the stump to the cars, practically all single-hauling, at a camp on the flat to the west of the Cascades in Washington in 1912, amounted to $0.965 per thousand feet. It includes the cost of yarding, moving donkeys, changing lines, raising gin poles, loading, and laying and lifting spur railroad track. It is unusual to segregate the cost of laying and lifting track in this way. A gin pole was used in loading, the power being furnished by a drum on the yarder. The following gives the yarding and loading crew:

	Wages per day.
Hook tender	$4.50 to $5.00
Rigging slinger	4.00 to 4.50
2 choker men	3.00 to 3.25
Sniper	3.00 to 3.25
Knotter	2.75 to 3.00
2 swampers	2.75 to 3.00
Signalman	2.50 to 2.75
Chaser	3.00 to 3.25
Engineer	3.50 to 3.75
Fireman	2.50 to 2.75
Wood buck	2.50 to 2.75
Drum tender	3.00 to 3.25
Head loader	4.00 to 4.50
1 second loader	3.00 to 3.25
Section hands	2.50 to 2.75

The ground was practically level, never steep enough to cause the logs to run, quite free of ravines and pot holes, with little brush or down timber. It was seldom necessary to yard the logs more than 800 feet—the average maximum yarding distance being about 650 feet.

The timber, which was cutting out from 85,000 to 90,000 feet per acre, was second growth, dense, of good height, averaging about 30 inches in diameter at breast height. The logs averaged 550 feet in volume.

The engines were 10½ by 10¼ inch compound-geared yarders, equipped with loading drum.

The average output per yarder per yarding day was 58,500 feet, selling scale. The time on which this average is based includes the time consumed in moving the yarders from one setting to another, changing ends, raising gin poles, changing lines, etc., as well as the time consumed in transporting logs from the stump to the landing.

(3) The labor cost of transporting the logs from the stump to the landing, including single and double hauling, at a camp along the Columbia River in 1912, amounted to $0.746 per thousand feet. It is not possible to state exactly the proportion of timber double hauled. The amount, however, ranged from one-third to one-half of the total output.

This cost includes a part of the wages of the camp foreman, timekeeper, and bookkeeper, and all the wages of the scaler. It does not include the cost of moving the logging yarders from one setting to another, loading, or the construction of pole roads and landings.

The following crew was employed:

	Wages per day.
Hook tender	$5.00 to $6.00
Head rigging slinger	3.75 to 4.25
3 assistant rigging slingers	3.00 to 3.50
Sniper	3.00 to 3.25
Chaser	3.00 to 3.25
Signalman	2.50
Engineer	3.50

At times it was necessary to use four instead of three rigging slingers, besides the head rigging slinger, also an extra chaser and butt-chain-block man. Oil was burned in the machines at the landings. When double hauling, the following additional men were employed:

	Wages per day.
Engineer	$3.50
Chaser	3.25
Fireman	2.75
Wood buck	2.50

The average output delivered at the landing per yarding day amounted to 70,000 feet. The fact that part of the timber was double hauled should be taken into consideration when analyzing this statement. While it is the aim in double hauling so to place the logging engines that the swinging crew can handle the output of the yarding crew without delaying them, such is not always the case. There is no question that the yarding record would have been higher if all the logs had been yarded direct to the landing.

The country is mountainous, very rough, and badly broken up. The slopes in general are steep. No rock outcrops or cliffs were encountered.

About 100,000 feet of Douglas fir, spruce, cedar, and hemlock per acre were logged, 20,000 to 30,000 feet of hemlock being left standing. The logs averaged about 36 feet in length and 1,900 feet in volume when based on the camp scale, which was about 2 per cent lower than the selling scale.

The three yarders used during the year were compound geared, new, and up to date. Two of them were 10 by 13 inch; the other, 11 by 13 inch.

TABLE 17.—*Summary of yarding record.*

Species.	Scale.	Number of logs.	Volume of average log.
	Feet, b. m.		*Feet.*
Douglas fir	32,204,222	14,369	2,241
Spruce	829,157	497	1,667
Cedar	2,868,684	2,665	1,076
Hemlock	1,868,065	2,301	819
Totals	37,770,128	19,832	1,900

Number of yarding days		531
Average scale per yarding day	feet.	151,797
Average scale per yarder per day	do.	71,164
Average number of logs per yarder per day		37
Average scale per log	feet.	1,904
Culls and other logs not scaled		405

(4) The average labor cost of transporting the logs from the stump to the landing at a camp along the Columbia River in 1912 amounted to $1.189 per thousand feet. It is not possible to state the average distance from the stump to the landing. A large percentage of the timber was double hauled; some of it was triple hauled.

The chance from the standpoint of the ground was about an average one, as the country is not particularly rough or badly broken up. From the standpoint of brush, rotten stumps, and down timber it was a bad one. The average minimum yarding distance was about 900 feet.

About 45,000 feet per acre were cut, mostly hemlock. The trees averaged about 32 inches in diameter at breast height. On the average three 32-foot logs were cut from a tree.

The average output per yarder per yarding day amounted to 57,000 feet, the logs averaging about 650 feet in volume. The yarding time on which this output was based includes breakdowns, moves, etc., which did not take more than five hours.

The crew consisted of 1 hook tender, 2 rigging slingers, 2 choker men, 1 signalman, 1 sniper, 2 chasers, 1 engineer, 1 fireman, 1 wood buck, and 1 branding man.

(5) The average labor cost for yarding and loading at a camp on the west foothills of the Cascades in Washington in 1912 was $1.379 per thousand feet. This includes the cost of raising gin poles, but not the cost of constructing landings. The yarding and loading crew was made up as follows:

	Wages per day.
Hook tender	$5.00
Rigging slinger	3.50
Two choker men	3.25
Signalman	3.75
Sniper	3.00
Swamper	3.00
Chaser	3.25
Butt-and-chain-block tender	3.25
Engineer	3.75
Fireman	2.50
Drum tender	3.00
Head loader	4.50
Second loader	3.50

A gin pole was used for loading, power for loading being furnished by a drum on the yarder. Oil was used as fuel, but the services of a fireman were considered necessary. The fireman received one-fourth of a day's wages for firing up. The average output per yarder per yarding day was 37,500 feet.

The ground was both hilly and level. All the timber was yarded direct to the landing, that on the slopes being yarded downhill.

Forty-five per cent of the timber was cedar, the rest Douglas fir and hemlock. The logs averaged about 36 feet in length and 1,000 feet in volume.

Wire rope.—Most operators keep a wire-rope account, in which they include the cost of all wire rope used in the camp. A few camps classify this account into the headings "Wire rope" and "Rigging," including the cost of the rope used for main yarding, trip, straw, and loading lines other than crotch lines, under the former heading, and chokers, together with tag, yarding, and crotch lines, etc., under the latter. One can not determine from their records the respective costs of yarding, roading, and loading lines. Furthermore, the average cost arrived at at the end of the year, or some other period, is of necessity based on the inventory, which may be high or low. In many cases the operators get out monthly cost statements, including an amount for wire rope which is based on an estimate rather than on an inventory made up at the end of the month. Other camps ignore the value of the rope on hand and base the costs on purchases. This does not represent the true cost, and is misleading when one is not acquainted with the method used. At one camp where this latter method was used the wire-rope cost per thousand feet by months for a period of five months was as follows: January, $0.882; February, $0.276; March, $0.109; April, $0.053; May, $0.159.

The average cost per thousand feet of the wire rope used in transporting and loading logs to operators that deliver their output to tidewater or the Columbia River amounts to about $0.15. The average cost by certain regions in accordance with the above is as follows:

	Per 1,000 feet.
Puget Sound	$0.14
Columbia River	.15
Grays Harbor	.19
Willapa Harbor	.20

The above figures are based on a large number of camps and in no case on less than a year's time. The average cost for the Puget Sound region is based on 20 camps and an output of 896,000,000 feet. In this region the lowest cost for any camp was $0.07; the highest, $0.27. The cost at 7 camps ranged from $0.10 to $0.12; at 4 camps, from $0.13 to $0.15; and at 5 camps, from $0.16 to $0.19. The average cost for the Columbia River is based on 10 camps and an output of 385,000,000 feet. In this region the lowest cost for any camp was $0.08; the highest, $0.23. The cost at 3 camps ranged from $0.10 to $0.12; at 2 camps, from $0.13 to $0.15; at 4 camps, from $0.16 to $0.25. In the Grays Harbor and Willapa Harbor regions a great deal of long-distance pole-road roading is done, which explains the relatively higher costs. In these regions the highest cost was $0.30; the lowest, $0.13.

The cost of wire rope per thousand feet is a rather large item of expense, and varies considerably in different camps. The reasons for this variation are to be found in the following factors:

(*a*) *Life of lines.*—Generally speaking, main yarding lines should handle three, four, or five million feet. If a line is defective or the yarding chance is particularly bad, it may not serve to yard 2,000,000 feet. Not infrequently, because of defects, main yarding lines have to be discarded before they have handled as much as 1,000,000 feet. Occasionally, 10,000,000 feet or more are yarded with a main yarding line. Taking it straight through the region, in good and bad chances, main yarding lines possibly average 4,000,000 feet. They last longer as a rule in road (short haul on the ground) or swing work than in yarding work. Trip lines last longer than yarding lines. Some logging superintendents estimate that they last no longer; others, that they last nearly twice as long.

At one camp the main yarding lines used during one year averaged about 4,000,000 feet per line. Eight million feet were yarded with one main yarding line. One main yarding line lasted three weeks, another only two days. They were $1\frac{3}{8}$-inch lines. The country is mountainous and badly broken up, and the slopes for the most part are steep. The logs were moved both uphill and down. They averaged about 2,000 feet and were yarded an average maximum distance of 900 feet. At another camp the main yarding lines used during a year averaged 5,000,000 feet. They were $1\frac{1}{8}$-inch lines. The ground was practically level and quite free of down timber. The logs averaged about 550 feet in volume. At still another camp the $1\frac{1}{4}$-inch main yarding lines used during a year averaged 4,500,000 feet; the $\frac{5}{8}$-inch trip lines, 5,500,000 feet. The ground was badly broken up by potholes, hummocks, small ravines, etc. The topography was mixed, the ground being both hilly and level; where it was hilly, the logs were moved downhill. The volume of the average log was about 1,000 feet, and the average output per engine per yarding day about 40,000 feet.

(*b*) *Diameter of lines.*—The size of lines used determines to a great extent their total cost and their life.

The following recommendations have been made:

> That a $1\frac{1}{4}$-inch main yarding and a $\frac{9}{16}$-inch trip line should be used on 10 by 11 inch compound-geared yarding engines; a $1\frac{3}{8}$-inch main yarding and a $\frac{5}{8}$-inch trip line on 11 by 13 inch compound-geared yarding engines; a $1\frac{1}{2}$-inch main yarding and a $\frac{11}{16}$-inch or a $\frac{3}{4}$-inch trip line on 12 by 14 inch compound-geared yarding engines; and that a $\frac{3}{8}$-inch straw line be used on all engines.

It was assumed that a 10 by 11 inch engine would be used in comparatively level country where the difference in elevation would not exceed 75 feet, the largest log would not exceed 1,000 feet, and the maximum haul would not exceed 950 feet; that a 11 by 13 inch engine would be used in rolling country where the difference in elevation would not exceed 150 feet, the maximum log would not exceed 5,000 feet, and the maximum haul would not exceed 1,000 feet; that a 12 by 14 inch yarding engine would be used where conditions were more severe; and that the yarding would be done uphill whenever possible. These sizes are larger than those generally used. It may be, however, that the increased output will more than offset the additional cost for slightly larger cables.

As a rule the size of main-yarding lines ranges from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches; of trip lines from $\frac{1}{2}$ to $\frac{7}{8}$ inches. In one camp, where the logs yarded averaged about 2,000 feet, the country being mountainous and badly broken up, $1\frac{3}{8}$-inch main yarding and $\frac{7}{8}$-inch trip lines were used. In another camp, where the logs yarded averaged about 600 feet, the country being practically level, yarding lines were $1\frac{1}{4}$-inch and trip lines $\frac{1}{2}$ inch. In a third camp, where conditions were practically the same as those in the preceding camp, $1\frac{1}{8}$-inch main yarding and $\frac{5}{8}$-inch trip lines were used. In another camp, where the logs yarded averaged about 1,000 feet and the country was bad, the main yarding and trip lines were $1\frac{1}{4}$-inch and $\frac{3}{4}$-inch, respectively. In still another camp the following lines were used: A $1\frac{1}{8}$-inch main line and a $\frac{5}{8}$-inch trip line with a compound-geared engine; a $1\frac{1}{4}$-inch main line and a ¾-inch trip line with a 11 by 13 inch compound-geared engine; and a 1¼-inch main line and a ⅞-inch trip line with a scraping engine.

(*c*) *Cost per foot.*—The cost of wire rope per foot varies considerably, depending on the type of construction, the grade of material used, and economic conditions. For selling prices see "Ground yarding equipment."

(*d*) *Length of lines.*—It is obvious that the cost per thousand feet depends on the length of the lines; that it is larger where long lines rather than short ones are used. Main lines used in yarding range in length from 900 to 1,500 feet, averaging about 1,200 feet. Trip lines are about two and one-half times as long as the main yarding lines; straw lines, as long as trip lines.

(*e*) *Number of lines.*—If much of the timber has to be double hauled over the ground, the cost of wire rope per thousand feet is considerably higher than where it is all single hauled. If some of it has to be handled by three or more engines, the effect is to increase further the wire-rope cost.

(*f*) *Ground conditions.*—The lay of the land and the character of the soil has a direct bearing on the wire-rope cost. Steep, broken, rocky ground is harder on lines than comparatively level land with clay for the lines to work on.

(*g*) *Care of lines.*—The cost of wire rope depends to a great extent on the care given the lines. More attention is paid to the main yarding lines than to the others. There are few operators who do not keep pretty close track of the main yarding lines. There are not many who can tell if the other lines are giving good service, and yet the cost of the main yarding lines represents only about one-half of the wire-rope cost. All operators do not exercise as much care as possible in stringing out the trip lines to the end that friction may be reduced to a minimum. Some operators prolong the life of the main yarding line through frequent splicing or by turning the line end for end on the drum.

The effect of most of the factors mentioned above is shown by the following table and the accompanying discussions:

TABLE 18.—*Cost of wire rope.*

Camp.	Time.	Year.	Cost per thousand feet.
1	6 months	1912	$0.072
2	1 year	1912	.108
3	1 year	1912	.197
	1 year	1911	.15
4	1 year	1912	.142
5	1 year	1912	.229
	1 year	1911	.403
	1 year	1910	.495

The cost at camp 1 includes the wire rope used in yarding and loading, including the rope used for chokers, tag lines, straps, etc. Straw lines were not used. One and one-eighth-inch rope was used for the main yarding lines; one-half-inch rope for the trip lines. Logs were single hauled a maximum distance of about 900 feet. The ground was practically level, quite free of pot holes and down timber, and contained little rocky material. The logs averaged about 550 feet in volume, and 10 by 11 inch yarding engines were used. A gin pole and crotch line were used in loading, the motive power being furnished by a drum on the engine.

The cost at camp 2 includes the wire rope used for the main yarding, trip, and main loading lines. It does not include chokers and tag lines used in yarding, and the crotch lines used in loading, which cost $0.045 per thousand feet. One and one-fourth-inch rope was used for the main yarding lines, five-eighths-inch rope for the trip lines, 1⅛-inch rope for the loading lines. All the timber was single hauled an average maximum distance of about 800 feet. The ground was practically level and contained no rocky material. Not less than two logs were yarded at a trip, sometimes three or four, and occasionally as many as five. The yarding engines were driven at practically their highest speed, so that, relatively speaking, the lines had hard usage. The logs averaged about 600 feet in volume. The yarding engines were 10 by 11 inch, compound-geared.

The cost at camp 3 includes the wire rope used in yarding and loading, also chokers, tag lines, crotch lines, etc. All timber was yarded direct to the landing at an average maximum distance of about 800 feet. The ground was of mixed topography, being badly broken up as regards minor features. The logs, averaging 1,000 feet in volume, were never moved uphill.

The cost at camp 4 includes the wire rope used for main yarding, trip, and main loading lines. It does not include the cost of rope used for chokers, tag lines, etc., used in yarding, and crotch lines used in loading. The chance, from the standpoint of the ground, was an average one, as the country is not particularly rough or badly broken up. From the standpoint of brush, rotten stumps, and down timber, it was much worse than the average. Part of the timber was double hauled, just how much is not known. The volume of the average log was about 675 feet.

The cost at camp 5 in 1912 includes the wire rope used for main yarding, trip, and main loading lines. It does not include the cost of chokers, tag lines, etc., used in yarding, and crotch lines used in loading, which cost $0.064 per thousand feet. One and one-fourth and 1⅜-inch rope were used for the main yarding lines; ⅞-inch rope for the trip lines. The country is mountainous and badly broken up, the slopes being generally steep. Logs were moved both uphill and downhill. No rock was encountered. The logs, averaging 1,800 feet in volume, were yarded an average maximum distance of 900 feet. About one-third of the timber was double hauled. The average scale per engine per yarding day was 70,000 feet. The cost for 1911 included all the wire rope used in camp. It is not possible to state the average maximum distance from the stump to the landings. Most of the timber was moved 2,000 feet by logging engines, a considerable amount 4,000 feet and a small amount 7,500 feet. The cost for 1910 includes the same items as the cost for 1911.

In estimating the cost of wire rope in connection with timber-appraisal work, two methods may be used. The first is to use the actual cost per thousand feet in a camp where conditions are approximately the same as the case being dealt with. The second is to develop the average cost in a more or less hypothetical way. A third method would be to check the results given by the second against the first. The following tables illustrate the second method in connection with single hauling.

TABLE 19.—*Estimated cost by second method.*

CASE 1.

Kind of line.	Size.	Length.	Cost per foot.	Cost per line.	Freight.	Total cost.	Output.	Cost per 1,000 feet.
	Inches.	*Feet.*	*Cents.*	*Dollars.*	*Dollars.*	*Dollars.*	*Feet.*	*Dollars.*
Main yarding	1¼	1,200	32.50	390.00	7.35	397.35	4,000,000	0.093
Trip	9/16	2,500	8.00	170.00	3.00	173.00	8,000,000	0.0216
Straw	⅜	2,500	6.25	156.25	3.00	159.25	25,000,000	0.006
Total				716.25	13.35	729.60		0.1206

CASE 2.

Kind of line.	Size.	Length.	Cost per foot.	Cost per line.	Freight.	Total cost.	Output.	Cost per 1,000 feet.
Main yarding	1⅜	1,200	40.00	480.00	9.00	489.00	4,000,000	0.1220
Trip	⅝	2,500	10.00	250.00	3.88	253.88	8,000,000	0.0317
Straw	⅜	2,500	6.25	156.25	3.00	159.25	25,000,000	0.006
Total				886.25	15.88	902.13		0.1597

Rigging.—While it is the practice of most operators to include in the wire-rope account all the wire rope used, a few operators keep a rigging account, in which they may include crotch lines used in loading, yarding (not main yarding), and tag lines used in yarding, chokers, and straps.

It is not possible to discuss the cost of rigging per thousand feet except in a general way, largely because operators as a class have paid little attention to keeping records of this expense.

The maintenance or replacement of chokers is the largest item of expense in a rigging account and varies with conditions the same as the cost of main yarding lines, and for the same reasons. The cost is higher where practically all chokers are made from new rope than where one-half or more of the chokers are made from old main yarding lines. Taking it straight through the region, the cost per thousand feet for chokers used in connection with ground yarding probably ranges from $0.03 to $0.05, the cost in hard chances running a little higher. The cost of tag and yarding lines, straps, etc., amounts to about $0.01 per thousand feet. Loading lines are discussed under "Loading."

The cost of rigging, including chokers, tag lines, yarding lines, etc., and not including the main loading line, at one camp amounted to $0.064 per thousand feet. It would seem that the cost should never be higher than this. The country was mountainous and badly broken up, the slopes for the most part being steep. Logs were moved both up and downhill. The yarding engines were powerful and output was not sacrificed to reduce the wear and tear on equipment. The logs averaged about 1,850 feet in volume. Most of the rigging was made from new wire rope. The cost of rigging, including chokers, tag lines, crotch lines, etc., and not including the main loading lines, at another camp amounted to $0.044 per thousand feet. The country was not particularly rough or badly broken up. The logs averaged about 700 feet in volume, one, two, three, or four logs being brought in at a trip, depending on conditions. The yarding engines were powerful and driven at high speed, most stress being laid on output. The rigging for the most part was made from new rope. At another camp the cost of rigging, including chokers, tag, yarding, and crotch lines, etc., and not including main loading lines, amounted to $0.057 per thousand feet. The country was practically level. Never less than two logs were yarded at a trip, sometimes three, four, or five. The logs averaged about 700 feet in volume. The yarding engines were driven at high speed.

Blocks, hooks, and rollers.—Very few operators keep account of the replacement and maintenance cost of blocks, hooks, and rollers. It does not, however, amount to much, ranging from $0.02 to $0.03 per thousand feet, including labor, repair parts, and materials.

At one camp the replacement and maintenance cost of blocks, hooks, and rollers used in yarding and loading amounted to $0.024 per thousand feet. The country was mountainous and badly broken up, the slopes for the most part being steep. Logs were moved both uphill and downhill. About one-third of the timber was double hauled. The logs, which averaged about 1,900 feet in volume, were yarded an average maximum distance of about 900 feet.

Fuel.—Most operators use wood for fuel in ground yarding engines; a considerable number, fuel oil; and a very limited number, coal. The use of wood is about the same in other methods of yarding and in swinging and roading.

Until quite recently wood has been the common fuel for logging engines. It was close at hand, was seemingly cheap, easy on the flues, and gave sufficient steam. With the modern, high-speed, powerful logging engine, even with an enlarged fire box, it did not prove so satisfactory, and, with the advent of equipment that made the use of oil a practical matter, it began to give way to fuel oil.

The amount of wood consumed in a logging engine in a day depends on the amount of work done and the character of the wood, and varies considerably. This is also true of the cost, although it does not vary to such an extent, since certain costs are comparatively fixed. Regardless of the amount of wood consumed, a fireman and wood buck are needed at each yarding engine. One operator logging in large Douglas fir and using sound fir—most of it large—for fuel, kept a record and found that 1,650 feet of timber was consumed by each yarding engine per day. He was working the engines hard. This same operator estimated that it cost $18.13 per day to supply steam for a yarding engine working under ordinary conditions when using wood, on the basis of the following assumptions:

Average daily wood consumption, 1,650 feet.
Average stumpage value, $3 per 1,000 feet.
Average logging cost, $4 per 1,000 feet.
Additional logging cost for wood logs, $0.50 per 1,000 feet.
One fireman, $3 per day.
One wood buck, $2.75 per day.

Another operator estimated the fuel cost per yarding engine, per day, when using wood, at from $14 to $18.

In some camps, cull logs are utilized as fuel. Where this is the case, it would not be proper to include an item for stumpage in estimating the cost of fuel. Most camps, however, find it necessary to use sound logs because there is not a sufficient number of cull logs, or because the desired head of steam can not be held when certain classes of cull logs are used.

Several advantages are claimed for oil as fuel in logging engines. One is that it practically eliminates the fire hazard. Burning oil gives off few sparks, so that the danger always present in the dry season with wood or coal burning engines belching forth a cloud of fire-distributing sparks, is practically done away with. Under most conditions oil is cheaper. It is further claimed that the output per engine is from 15 to 25 per cent higher. This would be particularly true where large logs are moved uphill rather long distances. Until quite recently, however, loggers, as a class, have felt that oil was harder on the flues than wood, and there evidently were grounds for this belief. Through improvements in the burners, certain changes in the engines, devices for cleaning the flues, etc., this objectionable feature has seemingly been entirely or practically overcome, since at the present time, 35 large operators are using oil in their logging engines—the total number of installations amounting to about 140. Oil has not met with much favor as a fuel for logging engines working at points other than along railroads, particularly in the wintertime, since the oil has to be pumped out to these engines. Then, there are camps located away from the railroads and away from deep water that can not use it for the simple reason that they can not secure it. The delivery cost in other cases no doubt precludes its economic use. In August, 1916, the price of oil in bulk at Tacoma, Seattle, and Portland, was $1.20 per barrel; in the winter of 1914, $0.80 per barrel—a barrel of oil contains 42 gallons and weighs 325 pounds.

The amount of oil burned in a logging engine varies with the amount of work done and the care exercised in firing. It varies from 6 to 8 barrels per day with yarding engines, and is a little less in engines engaged in roading or swinging where the haul is relatively short and in overhead yarding. Probably not more than half this amount is consumed in loading engines.

An operator using three yarding engines—two 10½ by 10¼ inch and a 12 by 12 inch—stated that each engine consumed about 8 barrels of oil per yarding day. The average output of each engine per yarding day was about 80,000 feet, the maximum yarding distance amounting to 900 feet. Another operator working in rough country and using five 12 by 12 inch yarding engines stated that the fuel oil consumed averaged about 6 barrels per engine per yarding day. In another case four yarding engines, working a total of 533 machine days, consumed fuel oil at the rate of 7.8 barrels per engine per yarding day the first year oil was used as fuel. The next year with experience and after various changes had been made in the engines—such as doing away with the blowers and increasing the height of the stacks—the oil consumed averaged 6.1 barrels per engine per yarding day.

The following is a more or less detailed record of the oil consumed in three yarding engines:

(*a*) Logging engines, 11 by 13 inch; boiler, 66 by 120 inch, 200-pound working pressure, safety valve set at 185 pounds; time, 5 months; average daily consumption, 9.6 barrels; chance, rough ground; average log, 1,975 feet; maximum yarding distance, 1.300 feet; average yarding distance, 650 feet; average output per engine per yarding day, 80,500 feet. Cost of fuel oil per barrel delivered in tank on rear end of sled, $1.05, or $0.137 per thousand feet. It is estimated that had wood been used the fuel cost would have amounted to $0.225 per thousand feet, so that the burning of oil resulted in a saving of $0.088 per thousand feet.

(*b*) Logging engine, 11 by 13 inch; boiler, 66 by 120 inch, 200-pound working pressure, safety valve set at 175 pounds; time, 5 months; average daily consumption, 7.8 barrels; chance, ground was extremely rough, requiring at times the use of two lead blocks and a stump roller; average log, 1,870 feet; maximum yarding distance, 1,500 feet; average yarding distance, 750 feet; average output per engine per yarding day, 59,400 feet. Cost of fuel oil per barrel delivered in tank on rear end of sled, $1.05, or $0.138 per thousand feet. It is estimated that had wood been used the fuel cost would have amounted to $0.305 per thousand feet, so that $0.167 per thousand feet was saved by burning oil.

(*c*) Logging engine, 11 by 13 inch; boiler, 66 by 120 inch, 200-pound working pressure, safety valve set at 185 pounds; time, 29¼ days; average daily consumption, 8.9 barrels; chance, up-hill yarding, the maximum lift amounting to 325 feet; maximum yarding distance, 1,200 feet; average yarding distance, 609 feet; average output, 98,700 feet. Cost of oil per barrel delivered in tank on rear end of sled, $1.05 per barrel, or $0.089 per thousand feet. It is estimated that had wood been used not more than 75,000 feet per day could have been yarded and the fuel cost would have amounted to $0.184 per thousand feet, so that $0.095 per thousand feet was saved by burning oil.

Those who have used coal in their logging engines feel that it has a decided advantage over wood. It does not, however, decrease the fire risk, neither is it a cheaper fuel than oil; so oil is preferred to coal, except in special cases where coal can be bought very cheaply.

The cost statements of operators do not show the cost of fuel consumed in logging engines as a separate item, and where wood is used the value of the merchantable timber consumed in this way is not charged against the cost of the logging. Since purchasers of national forest timber pay the same prices for merchantable timber consumed as fuel as for timber removed from the sale area, it is obvious that the cost of such material should be provided for in timber appraisals. Of course, if the character of the timber is such that it is clear that ample and satisfactory fuel can be secured from cull logs, the appraising officer will not make any allowance in his estimate. While it costs as much, or more, to deliver a wood log as a merchantable log alongside the logging engine, it may not be practicable for an appraising officer to take care of this cost under the heading "Fuel cost," since it can more easily be provided for in the estimated yarding output. The labor cost of preparing the wood for fuel can also be more easily taken care of under the heading "Yarding cost, labor."

The amount of sound wood consumed in a yarding engine ranges from 1,000 to 1,500 feet per day, depending for the most part on the size of the engine, the character of the country, and the amount of work done. Under ordinary conditions the amount consumed comes to about 20 feet per thousand feet of output. Figuring stumpage at $1.50 per thousand feet, the fuel cost of wood per thousand feet of output amounts to $0.03; stumpage at $2 per thousand feet, $0.04; stumpage at $2.50 per thousand feet, $0.05; stumpage at $3 per thousand feet, $0.06.

The amount of fuel oil consumed in a yarding engine ranges from 6 to 8 barrels per day. Under ordinary conditions the amount consumed amounts to about 5 gallons per thousand feet of output. On this basis, with the delivery cost of oil at $1 per barrel, the fuel cost of oil per thousand feet amounts to $0.12; with the delivery cost at $1.10 per barrel, $0.132; with the delivery cost at $1.20 per barrel, $0.144; with the delivery cost at $1.30 per barrel, $0.156.

A yarding engine consumes about 1½ tons of coal per day. On this basis, with a delivery cost of coal at $4.50 per ton, the cost of fuel per thousand feet amounts to about $0.135.

Lubricants, waste, and packing.—Few companies segregate the cost of lubricants, waste, and packing, and possibly no operator is in a position to say confidently what their cost amounts to per thousand feet yarded. The amount is small, about $0.01 per thousand feet. The fixed investment in the supplies is about $50 per yarding engine.

Maintenance of yarding engines.—Regardless of the care given ground engines, there will be breakdowns through wear, latent defects, or accidents. It is impossible to do more than approximate the maintenance cost per year on this class of equipment.

Seldom is the total cost of repairs on yarding engines, consisting in a general way of shop and miscellaneous labor, new parts, and repair materials, etc., segregated in such a way as to enable one to speak confidently of it. Besides, the maintenance cost varies with the size of the timber, character of ground, stability of sled. kind of settings, the speed at which the machines are driven, etc.

At one camp the cost of repairs on three yarding engines for one year amounted to $1,836, or $612 per engine. During the year some improvements were made on the engines, the cost of which is included in the above figures. The engines handled about 27,000,000 feet of timber. At another camp the repairs on two yarding engines for one year cost $422, or $211 per engine. The engines handled about 18,000,000 feet of timber. A year's upkeep of another yarding engine which handled 11,000,000 feet of timber amounted to $682. The year's repairs on two other yarding engines which handled 21,000,000 feet of timber averaged $357 per engine. A year's repairs on a yarding engine that handled 9,000,000 feet of timber amounted to $180. The above figures represent total costs, including labor, repair parts, material, etc.

Repair parts, materials, etc., other than labor, and iron and steel bars, for three $10\frac{1}{2}$ by $10\frac{1}{4}$ inch, compound-geared engines for six months cost $216, or $72 per engine. This is at the rate of $150 per engine per year. The engines were about 3 years old, working in better than average ground, and receiving good care. The repair parts, materials, etc., for six yarding engines for one year amounted to $1,200, which is at the rate of $200 per engine per year. The engines were about 5 years old and worked hard.

The total cost of taking out old flues and putting new ones in a yarding engine amounts to about $420, as follows:

Cost of 282 flues	$282.00
Cost of freight	6.00
Cost of 5 men for 7 days	134.00
	422.00

The cost of putting in a main-drum shaft amounts to about $244, as follows:

Cost of labor	$106.00
Cost of new shaft	131.00
Cost of freight	7.00
	244.00

Appraisers of National Forest timber estimate the annual cost of the upkeep of yarding engines at from 8 to 10 per cent of their original cost, the amount being equally divided between labor and material.

Depreciation on yarding engines.—No class of equipment is called upon for such extremely severe service as ground yarding engines. The demands made upon them are frequently far beyond their normal capacity. In addition, it is difficult to give them the attention they should have to keep them in good running order. This results in a relatively short life.

It is not possible to more than approximate the life of the ground yarding engines which are now being manufactured. There are several reasons why this is true:

(1) Ground yarding engines have undergone many changes, and those on the market are stronger than those built even a few years ago. The only basis for estimating the life of the present-day engine is the length of service secured from engines that have been or should have been discarded, taking into consideration the period of efficient service and the question of obsolesence. There are yarding engines working in camps that are 12 or 14 years of age. It may be, however, that it would be profitable to replace them with new engines; that the increased cost of logging, because of obsolesence and high maintenance costs, more than offsets the effect of a lower depreciation charge and a lower fixed investment.

(2) The life of yarding engines is frequently shortened through working them far beyond their efficient capacity, also through insufficient maintenance.

(3) It is frequently prolonged through unprofitable care.

(4) The industry has not kept cost records in such form as to enable one in a given case to say confidently when the efficient life has been passed.

Most operators place the efficient life of ground yarding engines at eight years. One of the leading operators of the region figures that it is economical to work his yarding engines hard for four years, sell them, and buy new ones. Possibly he works them harder than any other operator. If he can sell his engines at the end of four years for one-half of their original cost, which he hopes to do, it would seem that he figures on a life of about eight years.

For the purpose of arriving at the amount that should be written off annually for depreciation on this class of equipment, in connection with the appraisal of national forest timber, the efficient life of yarding engines has been placed at eight years, with a scrap value of 10 per cent of the original cost.

ESTIMATING THE COST OF YARDING.

The following hypothetical statement will serve to summarize the several items of expense in yarding and to show an estimated cost of yarding per thousand feet on the basis of an output of 60,000 feet per day per engine. It will also serve as a guide in estimating the total cost of yarding, including labor, supplies, repair parts and material, maintenance, depreciation, and supervision.

TABLE 20.—*Estimated total cost of ground yarding.*

Items.	Total daily cost.	Cost per 1,000 feet.
Labor cost	$39.60	$0.66
Wire rope		.136
Rigging		.03
Blocks, hooks, and rollers		.02
Fuel oil		.132
Lubricants, waste, and packing		.01
Depreciation on logging engine		.06
Maintenance of logging engine		.04
Woods water system		.02
Foreman, scaler, timekeeper, and bookkeeper		.04
Total		1.148

The labor cost is based on an average daily output of 60,000 feet, which takes into account both productive and unproductive time. It is assumed that no extra yarding engine is used, which means that the regular yarding crew moves the engine from one setting to another.

The crew, wages, and total daily labor cost are shown in the following statement:

	Unit.	Total.
1 hook tender	$6.00	$6.00
2 rigging slingers	3.60	7.20
2 choker men	3.50	7.00
1 chaser	3.40	3.40
1 swamper	3.25	3.25
1 sniper	3.25	3.25
1 signalman	3.00	3.00
1 engineer	3.75	3.75
1 fireman	2.75	2.75
		39.60

The wire-rope cost per thousand feet is based on the following assumptions: (1) The main line is 1¼ inches in diameter and 1,200 feet long; the trip line, five-eighths inch in diameter and 2,500 feet long; the straw line, three-eighths inch in diameter and 2,500 feet long; (2) that the main line will handle 4,000,000 feet of timber; the trip line, 8,000,000 feet; and the straw line, 25,000,000 feet; (3) that the selling price of wire rope is 50 per cent off the list price, and that the freight on a set of lines amounts to $13.35.

The rigging cost per thousand feet includes chockers, tag, and yarding lines, straps, etc.

The cost of fuel oil is based on the assumption that 5.04 gallons of oil will be burned per thousand feet of output and that the delivery price of oil is $1.10 per barrel (42 gallons).

The depreciation on the yarding engine includes the depreciation on a standard 12 by 12 inch, compound-geared yarding engine valued at $4,725, an extended fire box, fair-leaders, water tank, and yarding engine sled. It was assumed that the efficient life of the logging engine is eight years, with a scrap value of 10 per cent of the original cost. It was further assumed that the equipment would be used 25 days per month and 8 months per year, or to handle 12,000,000 feet per year.

The maintenance of the yarding engine includes the cost of the labor and repair parts and materials for the up-keep of a standard 12 by 12 inch, compound-geared yarding engine, together with an extended fire box, water tank, straw-line drum, and fair-leaders.

One month of the salaries of the foreman, scaler, timekeeper, and bookkeeper is charged against the side.

HIGH-LEAD YARDING.

High-lead yarding involves no great modification of ground yarding; the lead block is simply attached to a spar tree as high as practical from the ground instead of to a stump, so that the hauling line tends to lift the front end of the log from the ground. The introduction of high-lead yarding on a considerable scale is very recent, but has grown in popularity. It appears, in fact, to have followed the success of the overhead system, which does away with the necessity of constructing landings and has demonstrated advantages in log transportation.

High-lead yarding has been employed in the East for many years. A number of operators on the Pacific coast have no doubt used this system in a modified form at different times for short periods for several years. As early as 1906 a logging company in British Columbia used a high-lead system of the type used in the East; that is, with the yarding and loading engine mounted on a swivel-truck car. This installation was not immediately followed up by others. About 1912 another logging company in British Columbia started to use a high-lead yarding system that resembled those in use at present. It seems that the company's major reason for trying the system was to get away from the construction of landings. They found that the system, in addition to obviating the necessity of using landings, increased their yarding output. In 1916 a large number of operators were using the high-lead yarding system, and it looks as though it would supersede the ground system to a great extent.

The chief advantage of the high-lead system over the ground system is that there is a lift to the logs as they come in, so that they are not stopped so much by stumps and other obstructions, and travel faster. This advantage is greater the higher the lead block is fixed, but is lost in practice when the yarding distance exceeds 500 to 600 feet. Within these limits the front end of the log is elevated sufficiently to prevent nosing in soft ground and to provide free movement past stumps and windfalls. In working across canyons the high lead reduces the time lost through logs nosing into the bottom of the canyon or plowing into the opposite slope. Another advantage is that the landing place is kept relatively free of chunks, tops, and other trash, a source of trouble and expense with the ground system. It has been indicated that the high-lead system does not require landings, the resultant saving just about offsetting the extra expense of preparing the spar tree and swinging the lead block. In addition, yarding may proceed more constantly because the logs delivered at the landing place may be piled one on top of the other for some time, regardless of whether loading is going on or not.

When hauling down a steep slope the high-lead system probably is not so satisfactory as the ground system. In the case of side-hill work the logs have the same tendency to roll behind obstructions. It must be borne in mind also that much of the timber now being logged does not afford trees high and stiff enough for spar trees, and that it is expensive to maintain a rigging crew in some camps.

METHOD.

The method of high-lead yarding is illustrated by figure 34. A suitable tree conveniently located near the track is used as a spar tree. This tree, with the top cut off at from 120 to 200 feet from the ground, is guyed with from six to nine lines to give it rigidity. In the case of high spar trees there are usually six guys from the top and three from a point near the middle. If a double-line system of loading is used, two additional guys are necessary. A high-lead block, with a sheave from 24 to 36 inches in diameter, is hung near the top of the spar tree below the guy-line fastenings. The hauling line is passed from the drum of the engine to and through this block, and on and out to the logs to be yarded, the power being furnished by the trip line, as in the case of ground yarding. As a rule, no landings are built; but, owing to the large output secured, a loading engine in addition to the yarding engine is necessary in all cases. The yarding engine may be set at the base of the tree, or from 150 to 250 feet from it. In some cases the yarding and loading engines are mounted on an ordinary flat car or a special steel car with swivel trucks. (See guy-line loading under "Loading.")

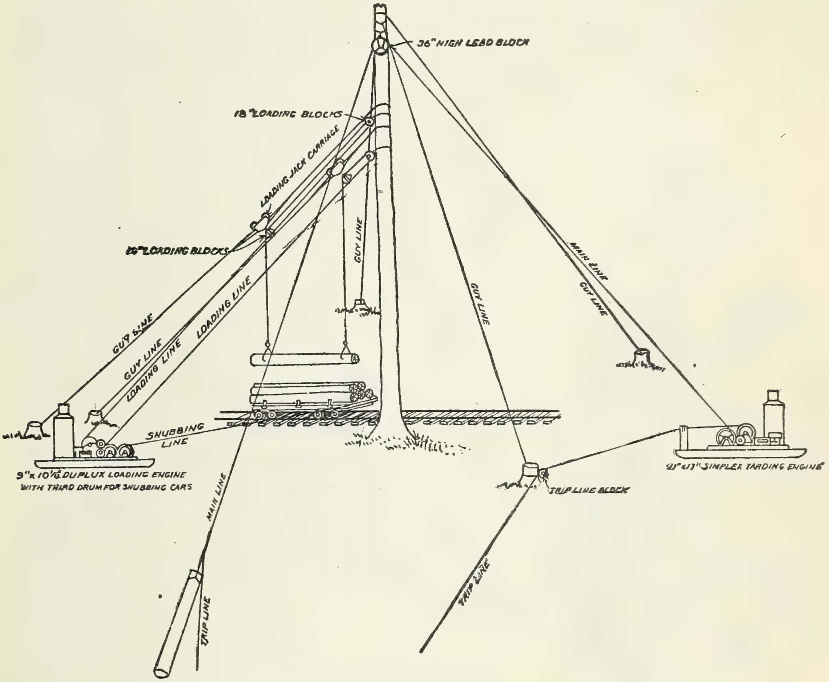

FIG. 34.—Location of equipment and improvements in high-lead yarding.

One company has found that the base of the spar tree should be from 14 to 20 feet from the center of the track. To insure the workmen against injury certain precautions are taken. The main-line lead block is hung in a 2-inch strap, the pins and shackles of these blocks being extra large. A "safety" guy is rigged under the bight of the main line in such a way that the main line will be deflected in case any of the rigging breaks. The bark on the spar tree is removed for several feet at the point where the lead block strap is attached, thus preventing it from being dislodged when yarding is in progress.

The general method of using a saw or ax to cut off the tops of trees selected for spars is both tedious and dangerous work. One company is using dynamite instead. The head rigger puts on a pair of long-spurred climbing irons and ascends the tree to the desired height, taking several sticks of dynamite with him. The dynamite, which is tied together end to end, like a string of sausages, is fastened securely around the tree at the point where he desires to remove the top. A detonating cap, to which a long piece of fuse is attached, is inserted in one of the sticks of dynamite. The rigger descends 20 feet or so, lights the fuse, and makes his way to a safe place on the ground some distance from the tree. After a few minutes the dynamite explodes, the tree top leaps into the air and comes crashing down. This way of removing the tops is only in the experimental stage at present.

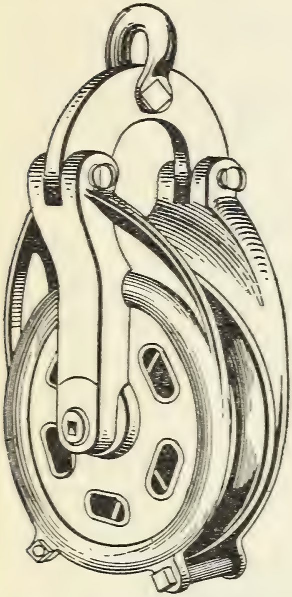

FIG. 35.—Auto-lubricating high-lead block.

EQUIPMENT.

The equipment used in high-lead yarding differs little from that used in ground yarding.

Yarding engines.—Any kind of two-drum yarding engines may be used. To take full advantage of the system, however, an engine with higher drum speeds than that of standard yarding engines should be used. One company, working on good ground and in second-growth timber where the logs average about 600 feet in volume, has purchased yarding engines designed especially for this system. These machines are simple geared, with 11 by 17 inch cylinders. Both main and trip drums are driven directly from pinions on the crank shaft without the interposition of counter shafts or idlers. The drums are narrow and of large capacity. The increased length of stroke compensates for the gear ratio involved in abolishing compound gearing. This type of yarder is also manufactured with 13 by 18 inch cylinder. The 11 by 17 inch engines cost about $5,500 and weigh about 55,000 pounds. Steel cars cost about $2,000; when they are equipped with air brakes, $2,200.

Lines and chokers.—Lines and chokers are of the same grade and construction as those used with the ground yarding system. The lines in both systems are of practically the same length, since the distances yarded are about the same. The main yarding line of the ground system is, of course, a little longer than that of the high-lead system. It is claimed that it is practicable to use lines of a little smaller diameter with the high lead than with the ground yarding system.

High-lead blocks.—While the desirability of a large lead block is clear, opinions differ as to the proper size. The sheaves of those in use range from 24 to 36 inches. One operator has found the smaller block satisfactory. There are several makes of high-lead blocks on the market. Figure 35 shows one of the autolubricating types. An ordinary butt-chain lead block was first used as a high-lead block, and some operators are still using the butt-chain lead block for this purpose. The size, weight, and net selling price of three sizes of autolubricating high-lead blocks are as follows:

TABLE 21.—*High-lead blocks.*

Number.	Size of sheaves.	Bearing.	Diameter of pin.	Oil capacity.	Weight.	Net selling price.
	Inches.	*Inches.*	*Inches.*	*Gallons.*	*Pounds.*	
1	24 by 5	7	3½	1½	485	$104
2	30 by 5	7	3½	1½	835	149
3	36 by 5	10	3½	2	970	167

EXTRA PARTS.

Items.	No. 1.	No. 2.	No. 3.
Tool steel shackle with clevis complete	$18.90	$21.00	$22.50
Shackle clevis and pin	6.75	6.75	6.75
Shackle pin with automatic lock	2.00	2.00	2.00
Pair steel block sides	38.00	67.00	72.00
Hardened steel pin	6.00	8.00	8.00
Bronze bushing	7.00	11.70	11.70
Manganese steel sheave, bronze bushed	47.25	67.00	77.00

The high-lead block is hung from 6 to 12 feet below the point where the guy cables are attached to the spar trees with a 1½ to 2 inch plow steel strap, wrapped either once or twice around the spar tree. As a matter of safety an additional strap is placed through the yoke of the block and loosely around the spar or one of the guy lines.

This second strap is intended to hold or slide the lead block slowly to the ground in the event the main strap breaks.

Trip-line blocks are the same as those used with the ground yarding system.

COST.

The high-lead method is the cheapest method of yarding under certain conditions. It has displaced the ground yarding system in many cases, and the overhead system in a few. It seems assured of a permanent field, but just how large can not be said at this writing.

Labor cost.—Yarding output, which, with all yarding systems, largely determines the labor cost, under proper conditions is from 15 to 30 per cent higher with the high lead than with the ground system.

The high-lead yarding crew is practically the same size as the ground yarding crew. A sniper is not necessary with the high-lead system, and the amount of powder used for clearing out yarding roads is negligible when compared with that used in connection with the ground yarding system. And, roughly, the same wages are paid. Under the same conditions, the total labor cost per day, aside from the labor cost for preparing spar trees, is practically the same with both systems.

The crew at one operation where the high-lead system was used in connection with practically level land and second-growth timber was as follows:

1 hooktender.
2 rigging men.
3 choker men or hook-on men.
1 swamper.
1 signalman.
1 chaser.
1 engineer.
2 wood buckers.

The guy-line system of loading (see the discussion of guy-line under "Loading") with one loading line was used. The yarding and loading engines were mounted on a flat car set on a siding at the base of the spar tree, steam for the loading engine being furnished by the yarding engine boiler. The loading engine or lever man was paid $5 per day. The chaser unhooked the logs when they were yarded to the landing place and hooked the logs when loading was in progress. In most cases the chaser has all he can do to unhook the logs and another man is needed to hook the logs in loading. There are times, of course, when the chaser can help with the loading. This time is by no means lost, since not infrequently the loading operation holds up the yarding, the help of the chaser tending to relieve this condition.

The company was averaging about 90,000 feet per yarder per yarding day with the high-lead system as against 60,000 feet with the ground-yarding system.

Two riggers were employed in the preparation of spar trees for two sides, the work taking about two-thirds of their time. In September, 1915, these men were paid as follows: Head rigger, $4 per day; second rigger, $3.50.

Another operator, working in large timber, has found that the labor cost for rigging a standing tree for a spar amounts to from $75 to $100. This includes the moving and setting of the loading engine and the taking down, bucking, and loading of spar trees that are not to be used again. Where the spar tree has to be raised—and this frequently has to be done to get the lead block in proper position for yarding—the labor cost for rigging runs from $100 to $200. In July, 1916, the riggers were paid as follows: Head rigger, $6 per day; second rigger, $4.

Inasmuch as spar trees take the place of two landings occurring on opposite sides of the track, the cost of spar trees in this case was about equal to the cost of the landings that were used with the ground-yarding system.

Other items of cost.—The cost of other items per thousand feet is a little less with this system than with the ground-yarding system. There are no landings to be built, which in one of the cases referred to above meant a saving of about $0.10 per thousand feet. One spar tree being used to yard on both sides of the track, the number of yarding engine moves is reduced. It does not take so long to change ends. The cost of the yarding lines is a little less, possibly 25 per cent. The cost of fuel and other supplies, the maintenance of equipment, as well as the amount written off for depreciation, is about the same with both systems.

OVERHEAD YARDING.

With the passing of the timber from the lower lands, logging operators in the region are confronted with the problem of handling logs—in many cases smaller logs—on rougher and steeper ground and over greater distances from the spur railroads. To do this work at the cost of past logging or less another method was necessary. Resort is being made, therefore, to an overhead or tight-line system.

While overhead logging methods have been employed for many years in the east, it is only within the last few years that they have been used to any extent by loggers of the Pacific Northwest. During a relatively short period they have reached the stage of dependable rigs, the output of which can be predicted with some degree of certainty, and the results secured so far give distinct promise of further improvement.

One operator has come to certain tentative conclusions with regard to the use and adaptability of overhead systems in coast timber, which may be summarized as follows:

(*a*) That overhead systems have little advantage over ground yarding systems in level or slightly sloping country and that they are not so satisfactory as the high-lead system on short hauls.

(*b*) That overhead logging can be successfully and economically employed on almost any kind of ground, provided the quantity of timber justifies the necessary expenditure for proper equipment. Some rough mountain sides have been logged from railroads at their base, and numerous other types of rough country have been logged at moderate expense that could not have been logged at all with other systems, practically considered.

(*c*) That the length of overhead line which can be successfully employed depends on the support which can be given the line, the weight of the load to be carried, the size of the line, the grade of the line in operation, and the deflection of the line. Wire rope is constructed to withstand certain pulls and stresses. The stress or tension on a cable suspended between two points is entirely different from that of any other type of rope application, and as a rule much greater than the stress expended by the suspended load. Too often conditions necessitate the use of an overhead cable with little sag or center deflection, and sag governs in a large measure the length of the cable. Putting it another way, the greater the deflection that can be secured the longer the cable that can be used.

(*d*) That machinery designed and built for ground logging is not adapted for overhead logging. Ground logging machinery is built for power and to withstand strains. Furthermore, there is no elasticity in its make-up. Under certain stresses the engine or the line may break. Overhead logging engines, on the other hand, should have high-speed drums and be so constructed as to refuse to handle any load in excess of that allowed by the factor of safety in the overhead line. Under certain conditions excessive strains on the overhead cable can be prevented by the arrangement of the other lines. Engines adapted for both ground yarding and overhead or high-lead yarding can now be purchased. These have two speeds—one for ground yarding, the other for overhead or high-lead yarding. The slow-speed pinion can be shifted in one-half hour's time, the result being that a high-speed engine adapted for overhead logging is converted into a slow-speed engine for ground yarding.

The bases of these conclusions are to be found in the peculiarities of the system. A wire hung between two supports along which the log travels suspended from a trolley is the characteristic feature. This arrangement results in both advantages and limitations. The advantages in the main are the reduction of friction and the fact that with a structure that costs very little as compared with a railroad or pole road logs can be yarded for long distances at a uniform speed. The limitations are fixed by the strength of the line as related to its own weight, the tension that has to be applied, and the service required of it. The load imposed by a turn of logs, great as it may be at times, is a small part of the normal burden. The tension necessary to keep it from sagging to the ground is greater on long reaches. That, combined with the weight of the line, in time exhausts its tensile powers.

These considerations, well understood by makers of wire rope and machinery, weighed heavily on the layout of the first attempt with this system. A thousand feet was the longest reach attempted. Trial, however, chiefly inaugurated by loggers under the spur of necessity, has demonstrated the practicability of longer reaches. Difference in elevation of the two cable supports is the key to the matter. This changes the forces on the line greatly, and as much of the ground to be logged compels just this arrangement the method has of late been successfully employed on two or three times the distance originally proposed. Not always, of course, does topography so lend itself. Intervening ridges may cut off the opportunity to stretch a cable for a long distance, or at least prevent the line from taking the sag which safeguards it.

Three methods which are used successfully are described. Two of these require special engines, and the other gives the best results when used in connection with a special engine. It should not be understood, however, that they are the only methods that have been used or that no other types of engines or line arrangements have been thought of. These methods have been used the most, have been given the most publicity, and probably represent the best principles so far evolved. The use of overhead logging methods for swinging or roading is dealt with under "Swinging."

LIDGERWOOD OVERHEAD SYSTEM.

The Lidgerwood overhead system consists of a standing wire cable suspended either between two trees, known as the head spar and the tail trees—the tree-rigged type (fig. 36)—or between a portable steel head spar and a tail tree—the portable spar type. In the tree-rigged type one end of the standing cable passes around the tail tree, being held in place by spikes, or over a tree shoe (fig. 37) suspended on the tail tree, and then down to a stump, to which it is made fast. The other end of this cable may be connected to a main cable extension (fig. 38) between the spar trees near the head spar by means of a block and fall tackle, the main cable being tightened with the aid of the engine; or the main cable may lead through a jack on the head spar (fig. 39) and then down to a stump, where it is connected. The latter is generally used in this region. The method of tightening is the same in both cases. The steel-spar type is provided with a steel head spar built upon the skidding car and carried with it. This steel spar carries all the head blocks and rigging, with all the lines reeved and in place.

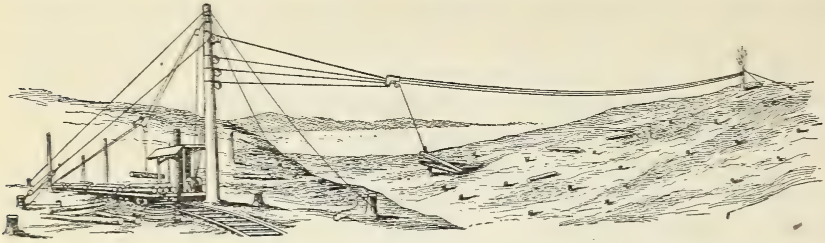

FIG. 36.—Location of equipment and improvements, Lidgerwood overhead system.

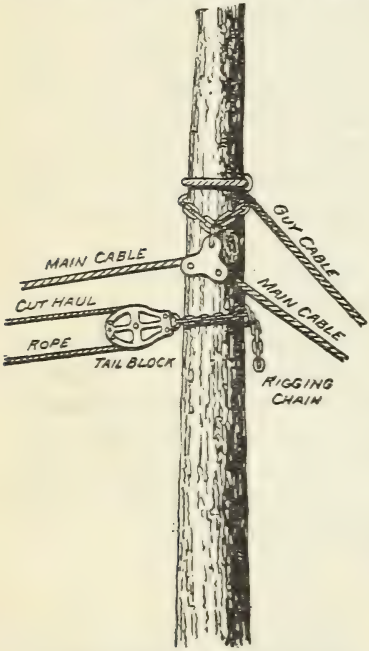

FIG. 37.—Tail tree, Lidgerwood overhead system.

A slack-pulling skidding or yarding carriage travels on the cable (fig. 40), being moved toward the head spar by the skidding or hauling line and toward the tail tree by the return or trip line. This carriage also carries the slack-pulling line, which enables the engine to give out the length of skidding line necessary to reach the logs lying to one side or the other of the overhead cable. Lines other than the main standing cable lead from their respective drums on the skidding engine through blocks on the head spar, or both the head spar and tail tree, and thence through the skidding carriage to their respective positions. In operation the overhead cable is stationary. An auxiliary engine is used to load the logs.

This system of yarding is a product of the East, having been used for a comparatively long time in the forests of the South and

Southeast. The original machine was invented by Horace V. Butters, of Ludington, Mich., in 1883. It was a crude device, which used manila rope for skidding lines; improvements made from time to time have brought it to its present state of efficiency.

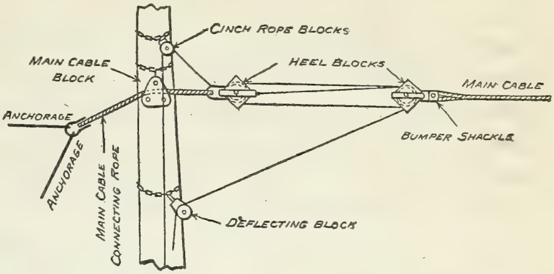

FIG. 38.—Block and fall outfit, Lidgerwood overhead system.

The first Lidgerwood overhead skidder on the Pacific coast was introduced in 1904. It was of the tree-rigged type and was the largest machine of this design built up to that time, having 10 by 12 inch skidding and 9 by 10 inch loading engines. While it did fairly satisfactory work from the beginning, several changes had to be made to adapt it to the new conditions. For the last 10 or 11 years it is said to have done satisfactory work. In 1907 several 12 by 12 inch overhead skidders were installed in the region. The following year a 12 by 12 inch skidder of a heavier type was introduced, and this is the type of machine that is now being used by a number of operators. The manufacturers of the skidder are now building a 13½ by 16 inch tree-rigged machine, which they hope will successfully handle any log required by the conditions in this region. During 1916 at least five coast operators purchased steel-tower skidders.

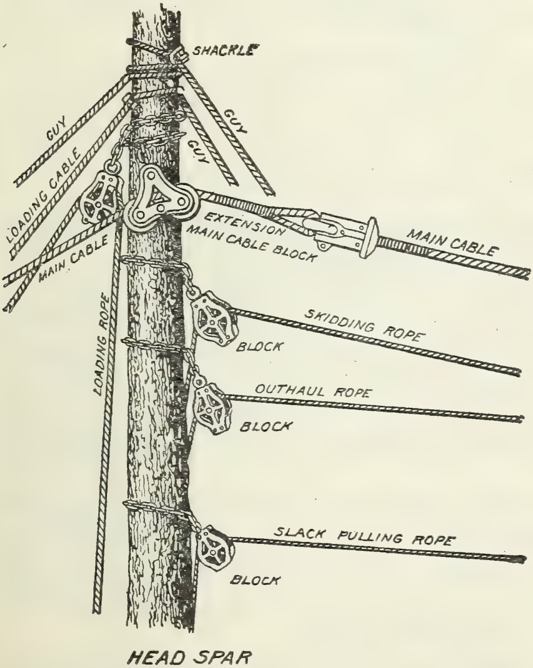

FIG. 39.—Main line extension, Lidgerwood overhead system.

Machines.—The tree-rigged machine of the type that has been installed within the last few years is made up of two sets of double engines, one for skidding and one for loading.

The main engine, or what is known as the skidding engine, has 12 by 12 inch cylinders and three drums. The back drum, the one next to the boilers, is known as the skidding line drum. This drum hauls the log in. The middle drum is known as the return or trip line drum. This is used not only to haul the carriage back to the woods but to hold the carriage in proper position when the log is being yarded under the carriage, also to regulate the speed of travel of the load when gravity carries it forward. The return line drum is provided with an interlocking and reversing device, which permits the interlocking of the skidder and receding line drum after the ends of the logs have been elevated sufficiently to clear obstructions. By means of this device the return line is paid out automatically as the skidding line is drawn in. The third drum from the boiler is the slack-pulling drum, which enables the engineer to pay out from the carriage the length of skidding line that is necessary to reach the logs that lie to one side or the other of the overhead cable. The slack-pulling drum has a friction device set with a tension of about 500 pounds, so that the line will not hang slack.

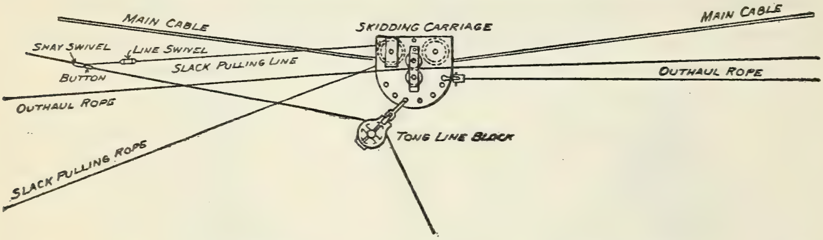

FIG. 40.—Skidding carriage, Lidgerwood overhead system.

The loading engine has double cylinders and four drums, two friction and two clutch drums. The friction drums are used in loading, but only one of them at a time. The two make it possible to shift the loading line from one side to the other, so that it is unnecessary for the loading engineer to look over the machine when loading is in progress. The two clutch drums are used for raising the main cable, rigging, etc.

The machine, as a rule, is mounted on a steel car, which is 22 by 8 feet and is equipped with a jack at each corner and swivel trucks. With this equipment it is possible to jack up the car, turn the trucks, lay short pieces of steel rail under the car wheels at right angles to the track, and move the car from the track.

The skidder may be mounted on a sled; in fact, some operators find it suits their purpose best to mount it this way. No other method could be used where it is necessary to place the skidder at some point other than along the track.

There are in use in the United States seven types of steel spar-skidders, each made in several different sizes. The one designed to handle timber of average size in this region is equipped with 12 by 12 inch, double-cylinder, high-speed engines, with five drums. Then there is the utility engine with 10 by 10 inch cylinders and four drums. On the front of the machine there is a 12 by 12 inch swinging-boom loading engine, mounted on a turntable. This engine drives three friction drums. Up in the tower, underneath the steel spar, there is a four-drum, guy-tightening engine. The skidding engine has a hauling-line speed of from 500 to 800 feet per minute, and a return-line speed of from 1,800 to 3,000 feet per minute. The machine is mounted on a steel frame. This frame with its supporting legs is raised or lowered by hydraulic jacks, to allow empty cars to pass beneath it.

The selling prices of the skidder and loading engine f. o. b. Portland or Seattle, exclusive of blocks and lines, were approximately as follows in 1916:

Prices of skidder and loading engine.

TREE-RIGGED TYPE.

(1) 12 by 12 inch skidder, 10 by 10 inch loading engine, mounted on a steel car	$11,500
(2) 12 by 12 inch skidder, 10 by 12 inch loading engine, mounted on a steel car	12,500
(3) 12 by 12 inch skidder, 12 by 12 inch loading engine, mounted on a steel car	13,000
(4) 12 by 12 inch skidder adapted for mounting on a wooden sled	9,500
(5) 13½ by 16 inch skidder adapted for mounting on a wooden sled	22,000
(6) 12 by 12 inch skidder, 10 by 10 inch loading engine, adapted for mounting on a wooden sled	9,700
(7) 12 by 12 inch skidder, 10 by 12 inch loading engine, adapted for mounting on a wooden sled	10,700
(8) 12 by 12 inch skidder, 12 by 12 inch loading engine, adapted for mounting on a wooden sled	12,500
(9) 13½ by 16 inch skidder, 10 by 10 inch loading engine, mounted on a steel car	23,000
(10) 13½ by 16 inch skidder, 10 by 12 inch loading engine, mounted on a steel car	26,000
(11) 13½ by 16 inch skidder, 12 by 12 inch loading engine, mounted on a steel car	32,000

STEEL-SPAR TYPE.

(1) 12 by 12 inch skidder, 10 by 12 inch loading engine, mounted on a steel car	28,000
(2) 12 by 12 inch skidder, 12 by 12 inch loading engine, mounted on a steel car	32,000

Main cable supports.—In the case of the tree-rigged system trees support the main cable (fig. 36). The head spar, only one of which is required to log an entire setting, may be a tree that, as a result of accident or design, is located at the proper place; or it may be a pole erected there. The head spar is from 100 to 150 feet in height and about 30 inches in diameter at the top. If a tree is used, and such is usually the case, the top is cut off to protect the workers and the machine from falling limbs. The head spar is braced with from six to nine guys attached to the top of the spar or at both the top and middle. The tail trees are selected before felling begins and are left standing, although occasionally a top is cut off to avoid trouble. The tail trees are also guyed.

The distance between the main cable supports (fig. 41) ordinarily ranges from 800 to 1,400 feet, which means that an area of from 40 to 100 acres can be logged at one setting. Logs can be yarded as far as 200 feet behind the tail tree. On steep mountain sides, the skidder may be rigged to yard logs 2,000 feet or more; in rare cases, up to 3,000 feet.

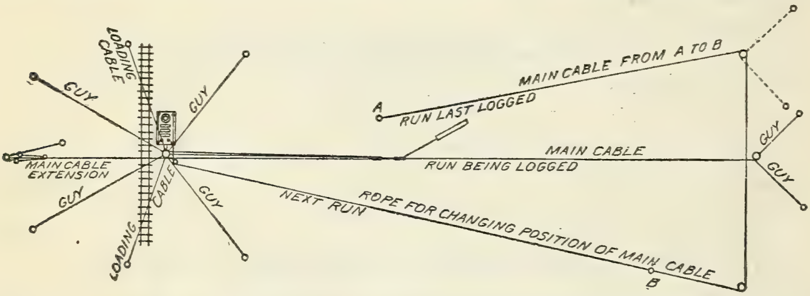

FIG. 41.—Location of roads, Lidgerwood overhead system.

It is necessary to use a new tail tree with every run. The distance between the runs depends on several factors, such as the character of the ground, size of timber, density of stand, location of suitable tail trees, etc. The tail trees are usually from 150 to 250 feet apart. The closer they are together, the easier it is for the tong men, and the more work it means for the rigging crew. The best results with this system are ordinarily obtained when the skidder is hauling about 1,000 feet and the tail trees are about 150 feet apart.

Operation.—In operation, the return line draws the carriage out along the main cable. When the carriage reaches the place where the logs are to be picked up, the return line drum is thrown out of gear and the foot brake is applied, holding the carriage stationary. The tongs or chokers are then lowered to the ground by drawing in the slack-pulling line. After the slack is pulled, the tongs or chokers are carried out by the tong man, to the log or logs to be hauled and attached. The skidding rope is then drawn in, with the return line held taut. This keeps the carriage stationary. When the logs are elevated sufficiently at one end to clear obstructions, the skidding and return-line drums are interlocked and the skidding line drawn in (the return line being simultaneously paid out) until the logs are brought to the landing places, where they are dropped ready to be loaded on the cars. The operation of the drum is then reversed and the carriage returned to the woods at high speed by the return line. The operation is then repeated.

Changing lines.—Two main cables are employed. While one is being used in yarding, the rigging crew is at work getting the other in place on the next run. When all the timber on one run has been logged, the main cable is dropped by the lifting and lowering drum and taken out of the carriage. The other main cable, already brought to place by the riggers, is placed in the carriage, connected, and tightened up, the entire change of lines taking from 20 to 40 minutes. The rigging crew then delivers the main cable from the old run to a new one. A light changing or straw line, provided for the purpose, is drawn out by hand from the head spar tree on the new run, up to and around the newly selected tail tree, and thence to the tail tree that has just been deserted. The changing line is there made fast to the main cable left lying on the ground on the run last logged, and then, by means of a drum, drawn back to the head spar tree, thus dragging the main cable entirely around the new tail tree to a position between the head spar and tail tree on the new run, ready to be connected up when required.

Changing settings.—The manufacturers of the skidder state that the change from one setting to another with the tree-rigged type consumes from two to six hours. An operator who is using one of these machines stated that a change from one setting to another could be made in from one-half to three-fourths of a day, provided a double set of rigging is used; that where a single set of rigging is used, the time consumed in changing settings ranges from a day to a day and a quarter.

The loss of time in moving from one setting to another is not considerable when compared with the loss of time in changing the settings of ground yarding engines, since the skidder, as a rule, logs more than twice as large an area at a setting as the ground yarding engine. The skidding roads radiate around the head spar, and the timber on both sides of the track is yarded at one setting of the skidder.

The time consumed in changing settings with the steel-spar type is, of course, considerably smaller, ranging, it is said, from an hour and a half to two hours.

Equipment.—The kind, size, length, and selling price of the lines, also the fixed investment in the lines, are discussed under "Cost."

The number and type of blocks used with this system is indicated in Figures 37, 38, and 39. A complete set of these blocks f. o. b. Portland or Seattle costs from $1,500 to $2,000 and weighs from 18,000 to 22,000 pounds.

The type of carriage used is shown in Figure 40. These carriages f. o. b. Portland or Seattle cost from $400 to $500 and weigh from 1,000 to 1,200 pounds.

Output.—In general, the output with this system ranges from 50,000 to 100,000 feet per day. For short periods it may be greater or less than this. One skidder, where the maximum yarding distance was 1,000 feet, yarded 1,000,000 feet in five days. On steep mountain sides, where the yarding distance ranges from 2,000 to 2,500 feet, the output may range from 50,000 to 75,000 feet.

The average output per skidder per skidding day, on the basis of a month's time, in a camp where five skidders were used, was 80,000 feet. The largest output of any of these skidders in a day during this period was 182,000 feet. In this camp, during the same month, four ground yarding engines were operated, the average output per engine per yarding day amounting to 40,000 feet. The maximum yarding distance in the case of the skidders was 1,200 feet; in the case of the ground yarding engines, 700 feet. The logs yarded with both systems averaged about 800 feet in volume. Another operator, working a skidder and a ground yarding engine in chances of the same character, was getting about 75,000 feet per day with the skidder and about 40,000 feet with the ground engine. The timber was small, second growth, and the ground practically level. Still another operator was getting an output of about 90,000 feet per day with a skidder. The maximum yarding distance was 1,200 feet, the ground was practically level, and the logs averaged about 1,000 feet in volume. One operator who used the overhead skidder discussed the output as follows:

> As to the output, we are not in a position to say what the system will do in a good chance. We have used it in very rough, steep ground and in small timber. From May 1 to May 1 we worked 227½ days, being shut down during the month of July and having the usual Christmas shut down, and put in 9,164,000 feet, or a daily average of a little over 40,000 feet. This is not a large average, but, owing to the conditions, think it is better than we could have done with the ground yarding system. Our largest day was 84,000 feet and our best monthly average was 53,000 feet per day. In these averages the time consumed in moving has been counted in as working days.

Cost.—Nothing further than a general discussion of the elements of cost will be attempted. The factor of output, which has already been referred to, is of major importance. While the size of the crew used, with this or any overhead system of yarding is much the same as in the case of a ground system, there is some difference in the character of the work performed and the wages paid some members of the crew.

The crew used for skidding, loading, and rigging generally consists of from 16 to 18 men, made up as follows:

- Skidding crew:
  - 1 skidding engineer.
  - 1 fireman.
  - 1 wood buck.
  - 1 hook tender.
  - 2 or 3 choker men.
  - 1 unhooker.
  - 1 signalman.
- Rigging crew:
  - 1 head rigger.
  - 3 assistant riggers.
- Loading crew:
  - 1 loading engineer.
  - 3 loaders.

This crew is used in connection with a wood-burning skidder. If oil or coal is burned, a wood buck is not necessary. Sometimes five riggers are necessary. A knotter should be added to this crew, unless knotting is considered a part of the operation of felling and bucking.

The fireman, wood buck, hook tender, choker men, and signalman are paid approximately the same wages as in the case of the ground yarding system. For a discussion of the wages paid the loading engineer and loader, see the section headed "Loading." A skidding engineer, as a rule, is paid more than a ground yarding engineer, the wages of the former ranging from $4 to $5 per day. A head rigger is paid from $5 to $6 per day; the assistant riggers about the same as the choker men.

It is roughly estimated that a crew handling 40,000 feet per day costs about $50 per day; one handling 60,000 feet per day, about $55 per day; one handling 70,000 feet per day, about $60 per day; one handling 80,000 feet, about $63 per day; one handling 90,000 feet per day, about $66 per day; and one handling 100,000 feet per day, about $66 per day.

One crew, handling about 80,000 feet per day in large, second-growth timber on rolling ground, cost about $63 per day, as follows:

1 skidding engineer	$4.50
1 fireman	2.75
1 wood buck	2.75
1 hook tender	6.00
1 choker man	3.50
2 choker men, at $3.25	6.50
1 unhooker	3.50

1 signalman	$2.75
1 head rigger	5.50
1 second rigger	3.50
2 assistant riggers, at $3	6.00
1 loading engineer	5.00
1 head loader	4.50
1 assistant loader	3.50
1 assistant loader	3.25
Total	63.40

The labor cost per thousand feet on the basis of the above estimated total daily labor costs is approximately as follows:

Labor cost per thousand feet.

Output per day:	
40,000 feet	$1.25
50,000 feet	1.00
60,000 feet	.90
70,000 feet	.85
80,000 feet	.79
90,000 feet	.73
100,000 feet	.66

The cost of the maintenance or replacement of the lines depends, in the main, on the length of the span and the conditions under which the lines are used. The main standing lines in use have either hemp or wire centers, with a tendency toward the latter as their length is increased, and range from 1¼ to 1¾ inches, or even larger, in diameter. The other lines are of the usual kind. The skidding lines are made of either ⅞ or 1 inch rope. The approximate size of the other lines used is given in the following table. The length of the lines employed in any given case varies of necessity with the length of the span. This may range from 700 feet on level ground, where the cost of constructing railroads is low, to 2,500 or 3,000 feet on mountain sides where the construction of railroads is practically out of the question. In Table 22 the estimated cost of lines per thousand feet of timber is shown for spans of three different lengths, the lines being the same size in each case. It will be noted that the estimated life of each line in million-foot units is given. The estimated life of each line is approximately correct in most cases, with the exception of the standing line, which can not be safely estimated. The output given for the main cable is too high for some cases and too low for others. Both hemp and wire-center rope are used for main cables, other lines being made of hemp-center rope. The main cables included in the estimates are made of wire-center rope. The price of wire rope is given under "Ground yarding."

Table 22.—*Estimated cost of lines, per thousand feet of timber, with the overhead skidder.*

Type of line.	Diameter.	Life in million feet.	Net price per foot.	Case 1 (900-foot span).			Case 2 (1,200-foot span).			Case 3 (1,500-foot span).		
				Length.	Total cost.	Cost per M feet.	Length.	Total cost.	Cost per M feet.	Length.	Total cost.	Cost per M feet.
	Ins.			*Feet.*			*Feet.*			*Feet.*		
1 main cable	1⅜	15	$0.50	1,300	$650	$0.043	1,600	$800	$0.053	1,900	$950	$0.063
1 skidding line	1	10	.25	1,100	275	.027	1,400	350	.035	1,700	425	.045
1 return line	⅞	20	.20	2,100	420	.021	2,600	520	.026	3,200	640	.032
1 slack pulling line	⅝	10	.11	1,100	121	.012	1,400	154	.015	1,700	187	.019
1 straw line	½	20	.09	2,100	189	.01	2,600	234	.012	3,200	288	.014
1 tightening line	1	10	.20	800	160	.016	800	160	.016	800	160	.016
Loading guys	1⅜	30	.50	800	400	.014	800	400	.014	800	400	.014
Loading line	⅞	3	.20	250	50	.016	250	50	.016	250	50	.016
Guy lines	⅞	......	.20	2,200	440	....	2,200	440	....	2,200	440	....
1 main cable (extra)	1⅜	......	.50	1,300	650	....	1,600	800	....	1,900	950	....
Total	......	......	......	....	3,355	.159	....	3,908	.187	....	4,490	.219

Both chokers and tongs are used to attach the logs to the skidding line. In some cases tongs furnish the sole attachment; in others, chokers. Both forms of attachment are sometimes used. Where only one tong is used it is attached to a ring on the end of the skidding line. Where more than one tong is used they are attached to the butt lines or chains, and the butt lines are attached to a ring on the end of the skidding line. Where chokers are used they are attached directly to the end of the skidding line, no butt chains being used. Sometimes one tong and one or more chokers are used, the tong being attached directly to the end of the skidding line.

The cost of chokers and butt lines per thousand feet does not amount to as much as in ground yarding (see discussion of rigging, cost under "Ground yarding"), probably ranging from 1 to 3 cents.

The cost of the replacement and maintenance of blocks, carriage, etc., no one is in a position to discuss confidently. The amount per thousand feet is small, ranging from 1 to 3 cents.

It is conservative to say that the cost of the fuel used in yarding and loading with this system, when the steam for the skidding and loading engine is supplied by a common boiler, is just about equal to the cost of the fuel used in yarding with a ground system.

The cost per thousand feet for lubricants, waste, and packing used in skidding and loading with this system ranges from 1 to 2 cents. (See "Ground yarding.")

The cost of the upkeep of the skidder ranges from $30 to $40 per month. (See discussion of the maintenance cost of ground yarding engines under "Ground yarding.")

The manufacturers of this machine estimate its efficient life at 20 years. It may be that with proper maintenance this figure is not too high. However, it is no doubt too high to be used by a going concern or timber appraisers, at least in most cases. The factor of obsolescence, also the time the skidder can be used by an operator before it has to be disposed of, have a direct bearing on the amount that should be written off annually for depreciation. Conservatively, for the purpose of timber appraisal, the efficient life of a skidder should be placed at 10 years, with a scrap value of 10 per cent of the original cost. (See discussion of depreciation on ground yarding engines.)

MACFARLANE SKY-LINE SYSTEM.

The MacFarlane sky-line system differs from the Lidgerwood system in that no slack-pulling line is employed, the main cable upon which the carriage travels being raised or lowered when the system is in operation. The first step in the evolution of this system was taken in 1905. In that year Mr. C. E. MacFarlane was confronted with the problem of moving logs about 900 feet down a steep slope to the Kalama River, the elevation of the bench above the river amounting to 600 feet, with the slope in places so steep that it was difficult for a man to climb up. To move the logs down this slope on the ground was not practicable and there was not enough water in the river to permit the use of a chute. It was decided that some inexpensive overhead method would have to be used. The trip drum of an ordinary 8½ by 10 inch ground yarding engine, set at the top of the slope, was fitted with a double brake. A 1-inch plow steel cable was made fast to a stump on the opposite side of the river, led up the hill, and passed through a block suspended to a properly guyed tree about 60 feet from the ground. A ⅞-inch line ran from the main drum, through a block attached to the end of the main or overhead cable, and thence back around a stump, thus providing a purchase for raising the main cable. A five-eighths-inch trip line was strung about 150 feet to one side of the overhead cable and led through a block to the carriage.

In yarding a log, say, 150 feet from the main cable, the trip line pulled the carriage and main line over to the log, permitting the log to be hooked on; slack was then taken out of the main cable, thus elevating the log, by reeling in the ⅞-inch purchase line on the main drum, and the log was lowered down the hill by letting out the trip line. When the log reached the river the main cable was lowered, permitting the load to be unhooked. The device constituted an overhead snubbing system, since it relied on gravity to pull the logs in.

The cost of yarding logs by this system was considerably less than it would have been if a ground-yarding method had been used, the operator finding that the steep ground was logged as cheaply as some moderately level ground with the ground method. The logs ranged from 600 to 1,500 feet in volume.

Five men made up the yarding crew—an engineer, fireman, hook-tender, rigging slinger, and unhooker.

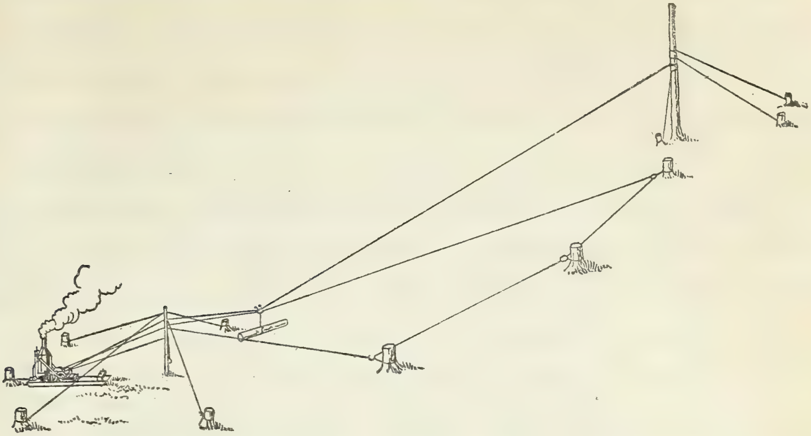

Fig. 42.—Location of equipment and improvements, MacFarlane sky-line system.

The Lidgerwood overhead system has been dealt with in considerable detail, so that only the points wherein the MacFarlane sky-line system differs from other overhead systems will be touched upon here. The location of equipment and improvements is shown in fig. 42.

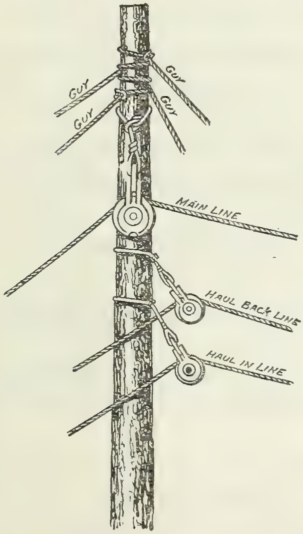

Fig. 43.—Head tree, MacFarlane system.

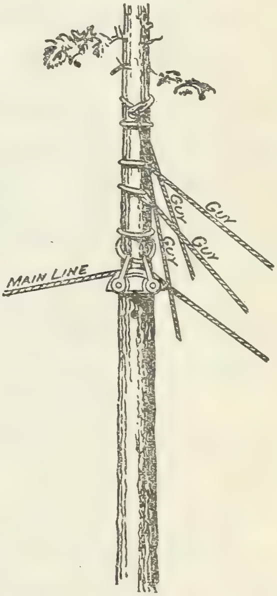

Fig. 44.—Tail tree, MacFarlane system.

Rigging.—The rigging consists of a main cable suspended between a head tree (fig. 43) and a tail tree (fig. 44). Upon this line the carriage travels. Two lines only are required to operate the carriage; one to haul it in, the other to haul it back. The main cable, leading from a drum on the logging engine, passes through a block suspended near the top of the head tree, thence out to and over a tree shoe suspended on the tail tree, and then down to a stump, where it is made fast. The haul-in line, leading from a second drum on the engine, passes through a block on the head tree in the same way as the main cable, and thence to the front end of the carriage, where it is made fast. The haul-back or trip line, leading from a third drum on the engine, passes along one side of the run, then through a block on the tail tree, and thence to the back end of the carriage.

The distance between the head and tail tree depends, of course, on the yarding distance, which in turn may be fixed by the practical range of the system. The system has been used successfully to yard logs a distance of 2,500 feet. The tail trees are from 150 to 300 feet apart, depending on conditions.

Operation.—The haul-back line hauls the carriage out along the main line to the point where the log is to be hooked on. Then the main cable is slackened sufficiently to lower the carriage to the ground, the haul-back line being used to pull the carriage to the log when the log lies to one side of the center of the run. When the choker or chokers have been attached to the carriage, the main cable is tightened until the front end of the load is raised far enough from the ground to clear obstructions. Powerful brakes on the main drum cable hold the main cable taut while the carriage with its load is pulled in. When the load is brought to the landing place, the main cable is lowered and then the load unhooked. The main cable is then tightened and the operation repeated. As logging on a run progresses, the corner trip block has to be shifted.

Logs can not be yarded from behind the tail tree, and it is difficult to yard logs on the outer edge of a wide strip near the tail tree. More power is required to raise the logs from the ground than with systems having a taut overhead cable, since the engine has to raise the cable as well as the log.

Changing lines.—One head tree is all that is required at each setting of the engine. The tail tree is changed each time a strip is logged, the new tail tree being selected and guyed before the old one is deserted. In changing lines, the lines are first drawn in to the head tree. The straw line, which is run before the change is started, is then used to run out the trip line. This operation takes from one to two hours.

Equipment.—The equipment is much the same as that used with other systems of overhead logging.

In 1911 a logging engine with four drums was built especially for use with this system. The main drum is driven through a compound train of gears by an internal gear, which revolves it in the same direction as the trip drum. The trip drum is a high-speed drum, which insures the quick return of the carriage. In front of these two drums are located the haul-in and straw-line drums. All the drums take the lead of the line on top.

The operating levers are conveniently located. The three principal drums are equipped with steam frictions, the throttles of which are banked in front of the engineer's position, immediately below the main throttle. The brake operating levers are mounted on the frame, within easy reach of the engineer's left hand.

The main and trip drums are each provided with powerful steam-operated brakes. The engineer controls the pressure exerted by the brake through the valve of the brake cylinder. The operating lever is connected to both the valve stem and cross head. When the lever is moved to any position opening the valve, the travel of the cross-head automatically closes the valve when the desired tension is reached. This forms a flexible control. The engine is mounted on a sled. The cylinders are 11 by 13 inch. The boiler, which is of the oblong fire-box type, is 66 inches in diameter. This engine costs about $9,000 f. o. b. Portland.

The length and diameter of the lines used with this system depend on the distance between the main cable supports and the size of the timber. As a rule the main cable ranges from 1¼ to 1¾ inches in diameter. The haul-in and haul-back cables are generally seven-eighths of an inch in diameter. When the main cable is 1¼ inches it generally leads direct to the main cable drum on the engine. If one of larger diameter is used it may be necessary to use a purchase line to increase the power of the engine. Under such conditions a block is attached to the main cable. The purchase line, leading from the main-line drum, passes through this block and then down to a stump between the head tree and the engine, where it is fastened.

One company hauling second-growth timber down a steep mountain side used the following lines:

Lines.	Type of construction.	Diameter.	Length.
		Inch.	*Feet.*
Overhead cable	6 by 19	1½	1,800
Haul-in line	6 by 19	⅞	2,000
Haul-back line	6 by 19	⅞	4,000
Straw line	6 by 19	⅜	4,000
Chokers	8 by 19	1⅛	20 to 30
Guys[1]	8 by 19	1¼	4,000

[1] Includes a set of guys for the tail tree.

NOTE.—The selling price of wire rope is discussed under "Ground Yarding."

The carriage has two sheaves, being light, simple, and strongly constructed. On the bottom is a large hook, to which the chokers are attached, and a small hook at each end, the haul-in line being attached to one, the haul-back line to the other. The carriage (fig. 45), with 16 by 3 inch manganese-steel sheaves, costs about $120.

The blocks are much the same as those used in high-lead yarding. The price of overhead blocks is given under "Loading." The following gives the number, types, and selling prices of blocks used with this system at one camp:

Type and size:	*Net selling price.*
1 14-inch tree jack (fig. 46)	$180
3 large moving blocks	150
2 yarding blocks	50
2 18-inch trip or haul-back blocks	50
6 14-inch trip or haul-back blocks	105
2 tree shoes (fig. 47)[1]	100

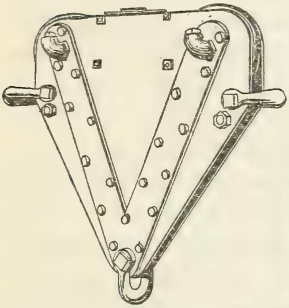
FIG. 45.—Double-sheave overhead carriage.

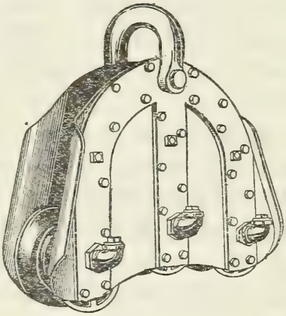
FIG. 46.—Tree jack.

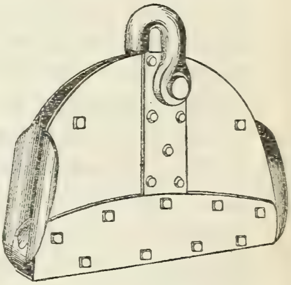
FIG. 47.—Tree shoe.

Output.—The output with this system ranges from 50,000 to 100,000 feet per day. At one camp where the logs were moved 1,500 feet down a steep slope the output averaged about 60,000 feet per day, the logs averaging about 800 feet in volume. In the same camp the output averaged from 85,000 to 100,000 feet per day on practically level ground, when the hauling distance did not exceed 1,000 feet. At another camp, where the logs were moved 2,000 feet down a steep mountain side, the output averaged about 50,000 feet per day, the logs averaging about 900 feet in volume. At still another camp, where the logs were moved about 1,600 feet down a steep slope, the country being badly broken up, the output ranged from 60,000 to 80,000 feet per day. In this latter case the timber was large, the logs averaging 2,000 feet in volume, and some of them containing 6,000 feet.

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[1] A tree shoe is used to support the overhead cable at the tail tree. Since the tightening is generally done at the head tree, the outer end of this cable is stationary, making a hardwood shoe instead of sheaves practical.

Cost.—Output is the telling factor in all systems of yarding. With the same output the cost of yarding is practically the same for all systems.

The following gives the crew and the wages paid per day at one operation:

Yarding crew.

1 hook tender	$4. 50
2 choker men	6. 50
1 unhooker	3. 25
1 signalman	3. 00
1 engineer	4. 00
1 fireman	3. 00
1 wood buck	3. 00
	27. 25

Loading crew.

1 fireman	2. 75
1 engineer	3. 25
1 head loader	4. 50
1 second loader	3. 50
1 third loader	3. 00
	17. 00

Rigging crew.

1 head climber	4. 00
1 second climber	3. 50
3 helpers	9. 00
	16. 50

It will be noted that this crew is a little larger than the ordinary crew that yards and loads logs with a ground yarding system, and that the size of the crew is practically the same as that used in connection with the Lidgerwood overhead system. A separate engine is used in loading. Under some conditions an additional choker man would be necessary.

NORTH BEND SYSTEM.

The evolving of the striking features of what is now known as the North Bend system is credited to Mr. R. W. Vinnedge, of Edgewick, Wash. It is used by a number of operators in this region because of its simplicity and the fact that it may be worked successfully with an ordinary ground yarding engine.

Rigging.—The carriage rides on a standing line. This standing line may be stretched from the tail tree to the head tree, and then anchored to stumps, as in the case of the tree-rigged Lidgerwood system; or it may lead from a drum on the engine as in the case of the MacFarlane sky-line system. The latter is the better method and is always used when the engine makes it possible. To relieve the engine of as much of the load as possible, a block purchase is used in tightening the line. The standing cable, as suggested by its name, is not raised or lowered when the system is in operation. Obviously, however, this could be done if conditions warranted. The haul-in line is attached to the carriage. In the bight of this line, between the carriage and head tree, a butt chain lead block is hung. To this block the load is attached. The haul-back line is run out along the strip from 100 to 150 feet from the standing line, in the same manner as in ground yarding, and attached to the carriage. This line is used, in connection with a properly located lead block, to draw to any desired point the block to which the load is to be attached. The layout is shown in figure 48.

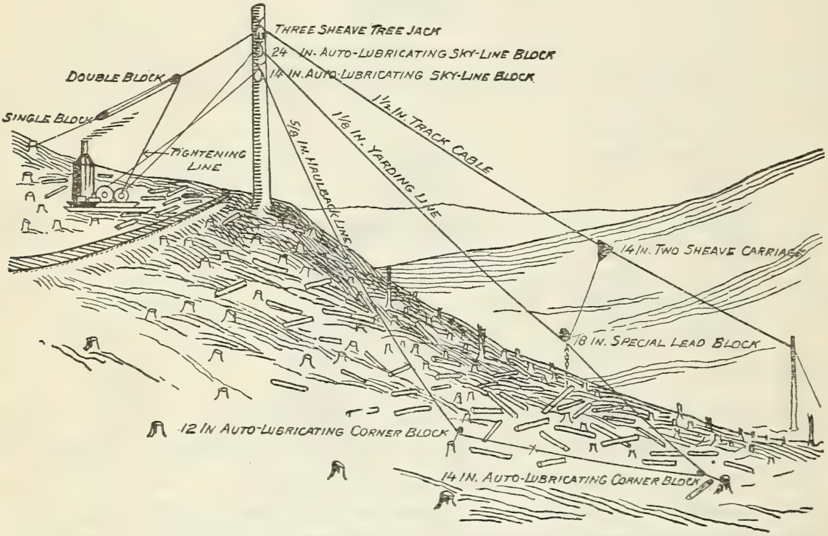
THREE SHEAVE TREE JACK
24 IN. AUTO-LUBRICATING SKY-LINE BLOCK
14 IN. AUTO-LUBRICATING SKY-LINE BLOCK
DOUBLE BLOCK
SINGLE BLOCK
TIGHTENING LINE
5/8 IN. HAULBACK LINE
1 1/8 IN. YARDING LINE
1 1/2 IN. TRACK CABLE
14 IN. TWO SHEAVE CARRIAGE
18 IN. SPECIAL LEAD BLOCK
12 IN AUTO-LUBRICATING CORNER BLOCK
14 IN. AUTO-LUBRICATING CORNER BLOCK

FIG. 48.—Location of equipment and improvements, North Bend system.

Equipment.—The equipment is practically the same as that used in the MacFarlane sky-line system.

An ordinary two-drum yarding engine may be used to furnish the power for this system. Mr. Vinnedge used a standard 11 by 13 inch compound-geared yarding engine with the first installation, securing very satisfactory results. To get the best results, however, an engine differing somewhat from the standard ground yarding engine should be used. An engine designed especially for use with the MacFarlane system fulfills the requirements nicely.

One operator, after convincing himself that this system would log parts of his holdings cheaper than a ground machine, decided that the best results would be secured with a special engine. He thought, however, that this special engine could be so designed as to serve for ground as well as overhead work. The basis of the resultant engine is one of the standard compound-geared yarding engines. It has 11 by 13 inch cylinders, four drums, and an extended fire-box type of boiler. The gear ratio was changed so that a considerable portion of the power exerted by the main-line drum was sacrificed for increased speed. The four drums are all located within the frame and rotate in the same direction, taking the lead of the line on top. The main and trip drums are located as in the case of an ordinary compound-geared yarding engine, the main drum being used to operate the standing line, the trip drum to return the carriage. Immediately in front of these two drums there is a shaft carrying the haul-in and straw-line drums. The gear on this shaft is driven through an intermediate gear, which meshes directly with the trip-drum gear. The haul-in drum has a capacity of 2,700 feet of 1⅛-inch line and a speed of about 600 feet per minute. The trip drum has a capacity of about 3,500 feet of ¾-inch line and a speed of about 1,500 feet per minute. This trip drum is equipped with a large steam-operated brake for the purpose of snubbing the load down steep slopes. The brake is so designed that a varying pressure is obtainable, making it possible for the engineer to control the log under all conditions. The main drum is equipped with a ratchet and pawl for holding the standing line, since it is seldom necessary to raise or lower it. This drum is also provided with a large brake, so that, with the pawl released, the standing line may be slackened gradually. The net price of the engine f. o. b. Portland is approximately $6,500.

The diameter and length of the standing line depend on the size of the timber, the length of the span, and the amount of deflection that can be secured. The standing lines used have ranged from 1¼ to 1½ inches in diameter. One operator who has had considerable experience with the system is of the opinion that a 1¼-inch cable is large enough for logs scaling 2,000 feet, and that 1⅜-inch cable should be used when the logs average from 2,000 to 4,000 feet in volume; that is, where the span does not exceed 1,500 feet. The system has given entire satisfaction when hauling as far as 1,600 feet.

The haul-in or yarding line is generally 1⅛ inches in diameter, the length depending on the distance between the head and tail tree, the distance logged on each side of the standing line, and the distance the engine is from the head tree. It is economical to yard logs lying from 150 to 200 feet on either side of the standing line. To go farther results in too much strain on the equipment, also the danger of uprooting the tail tree. The wear on the yarding line when yarding downhill is almost negligible, except on that portion on which the yarding block rides. The records of one company that is using this system to haul downhill show that one 1⅛-inch haul-in line was used to yard 9,0000,000 feet, the line retaining 50 per cent of its life when it was discarded and used for chokers. The wear on this line is much greater when yarding uphill or on level ground. Still, in no case is its life as short as the main yarding lines used for ground yarding. The haul-back lines in use range from nine-sixteenths to twelve-sixteenths inch in diameter. Straw lines are generally three-eighths inch in diameter.

SWINGING.

Among the loggers of the region it is generally considered good practice to build railroads within an economical yarding distance of the timber. It is not always possible, however, to do this. It may be cheaper, because of the cost of railroad construction or the quantity of the timber, to use two or more logging engines, with or without improvements, to transport the logs from the stump to the landing. The practice of using two or more engines to transport timber over the ground—that is, without improvements—from the stump to the landing is known both as swinging and roading. In this publication the operation will be referred to as swinging, the distance from the yarding engine to the landing or pole road being considered as the swinging distance. The use of overhead logging engines for the same purpose will also be considered as swinging.

The distance it pays to swing timber is governed largely by the topography and formation of the country and by the quantity of timber in the swinging unit that can not profitably be logged direct to the landing. Under most conditions timber can be swung farther with overhead than ground logging engines.

Swinging decreases the cost of railroad construction, but it increases the cost of transporting the logs from the stump to the landing. Theoretically speaking, it is the comparison of the cost of the two methods, taking into consideration the fact that the yarding and swinging at times delay each other, that indicates whether swinging should be resorted to in a given case.

GROUND SWINGING.

It has at times been found profitable to swing logs three or four thousand feet over the ground. At times it may prove cheaper to single-haul the timber 1,200 feet or more—if the drum capacity of the yarding engine will permit—than to double-haul it. At other times it is cheaper to double-haul a shorter distance than this. Not infrequently two swing engines, in addition to the yarding engine, are used, and occasionally three swing engines are necessary.

The distance between the swing engines depends to a great extent on the topography of the country, the aim being to place them in such a way that they will not hold up the yarding engine. Under ideal conditions the distance is a little greater than the maximum yarding distance.

In swinging, the yarding crew is the same as when the logs are single hauled. The crew used with a swing engine depends for the most part on the character of the country and output. As a rule, it is approximately as follows:

1 engineer.
1 fireman.
1 wood buck.
1 hooker on.
1 chaser.

If the chance is bad, an additional chaser may be necessary. In some cases no wood-buck wages, or only half the wages of a wood buck, are charged against this crew. The wages paid this class of labor are discussed under "Ground yarding."

The equipment, supplies, etc, used with a swing engine are practically the same as those used with a ground yarding engine. Both simple and compound geared engines are used. If the swinging distance is great, a simple-geared engine is used, since it has the larger drum capacity. Under most conditions the simple-geared engine is preferred. The maintenance, replacement, and depreciation of equipment, also the cost of supplies, in connection with swing engine are little less than with a ground yarding engine. (See "Ground yarding.")

OVERHEAD SWINGING.

In mountainous country overhead logging systems are particularly adapted for swinging, since on steep mountain sides logs may be swung 2,000 feet or more at a very small cost for improvements. Any one of the three systems of "overhead yarding" may be used to swing logs this distance, provided, of course, the lay of the land is such that the necessary deflection in the line can be secured.

In one case the operator was confronted with the problem of swinging timber 2,000 feet down a mountain side from a plateau to the railroad below. A ground yarding engine was set at the top of the hill, near the base of the tail tree, to assemble the logs to be swung. Eighteen hundred feet down the mountain side the head tree was located, the rise of the land for about one-half of this distance from the head tree being gentle, the rest being very abrupt, providing ample deflection for the standing line. A wide-drum ground engine was set at the railroad. The logs were swung from the tail tree at the top of the slope to the head tree by the North Bend overhead system, an especially constructed engine being used. They were hauled the remainder of the distance to the track by the ground engine, where they were loaded on cars with the gin pole and crotch line method. About 4,000,000 feet of timber was hauled by the sky line at this setting. The overhead swing engine had no trouble in taking care of the output of the yarding engine, which averaged from 50,000 to 75,000 feet per day; in fact, it seemed it could have handled the output of two yarding engines.

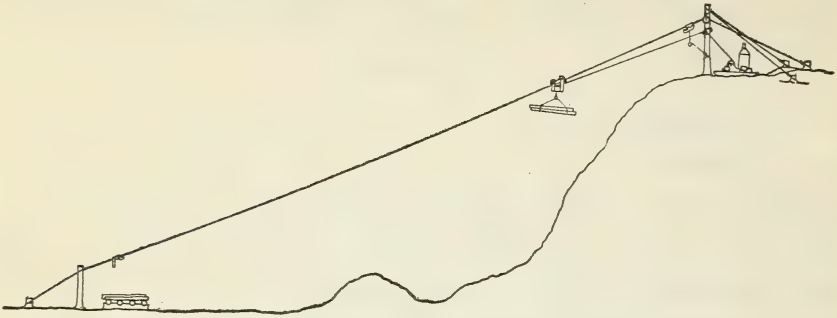

FIG. 49.—Nestos overhead snubbing system.

Under some conditions an overhead snubbing method can be used to swing logs to better advantage than any other method. This was true of the following case:

An operator had a limited amount of timber, which stood on a bench 400 feet above the railroad, the slope between the bench and the railroad falling away so rapidly that the use of a pole road or chute was out of the question. It was decided to use an overhead snubbing system of the type shown in figure 49.

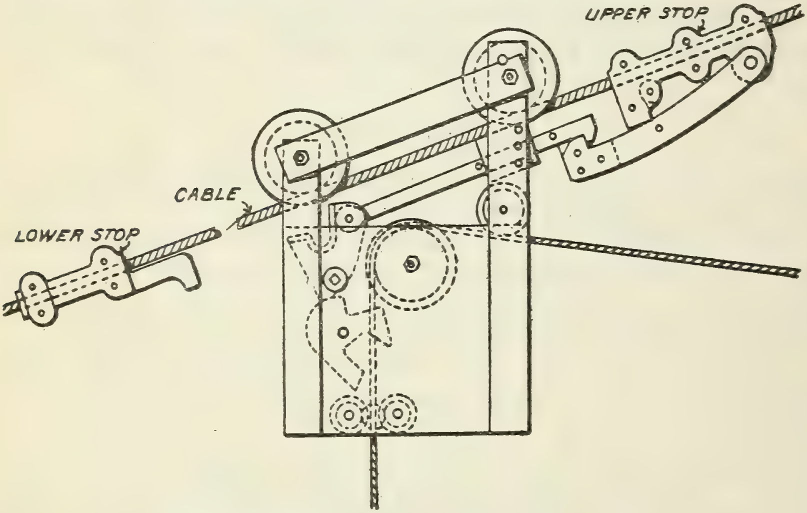

FIG. 50.—Carriage, Nestos overhead snubbing system.

A wire cable 1⅜ inches in diameter and 2,000 feet long was used as a standing line. One end of this line was fastened to a stump near the railroad and the other end was taken up the hill, passed through a block suspended to a guyed tree about 25 feet from the ground, and made fast to a stump. Two stops (fig. 50) were clamped on the standing line, one at the top where the logs were picked up, the other at the foot where the logs were landed.

A carriage of the design shown in figure 50 was used, the snubbing line leading through it to the load.

A 10 by 12 inch wide-drum yarding engine, on which an extra wide brake had been installed, was set at the top of the slope and used to lower the logs. Any friction drum engine with braking power sufficient to hold the load can be used. A three-drum engine could be used both to yard and lower the logs. To get the full capacity out of the system, however, one should use a separate engine with a special brake drum.

The load was hooked on the end of the snubbing line (fig. 51) and hoisted till a ball fixed on the snubbing line just above the hook engaged in a catch in the carriage. This catch held the load up. The snubbing-drum friction was then thrown off and the load was snubbed to the landing place. At this point the carriage came in contact with the stop on the lower end of the line. This stop held the carriage and freed the snubbing line, allowing the load to be lowered to the ground. When the load was unhooked the signal was given to return the carriage to the woods. The ball on the snubbing line again came in contact with the catch of the carriage, releasing the carriage from the stop.

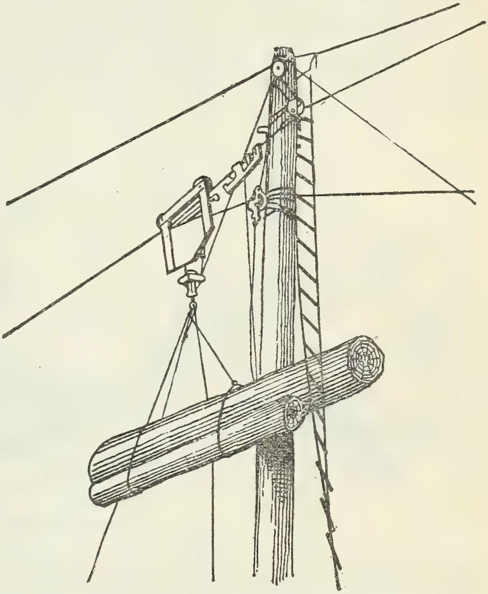

Fig. 51.—Method of hooking load, Nestos overhead snubbing system.

The following crew was used to operate the snubbing device:

1 engineer.
1 fireman.
1 wood buck (half time).
1 hooker on.

The loaders unhooked the loads at the landing. The chaser employed in the yarding crew, besides unhooking the logs as they were delivered to the snubber, assisted the hooker on in making up the loads for the snubber.

The operator was working in relatively small timber, and so was not in a position to say how large a log could be handled over the 1$\frac{3}{8}$-inch standing line. The largest loads handled did not exceed 2,000 feet.

The snubber handled the output of one yarding engine, about 60,000 feet per day, when working at seemingly no more than one-half capacity. When working intermittently it made 50 trips per day, and it could have made 75 trips per day easily.

In transporting large timber across canyons on a standing line, where conditions are such that the logs must be entirely suspended, some operators have found it necessary to use a double standing line. The rig used by one operator is shown in figure 52. The method of tightening the double standing line, which is made of 1$\frac{1}{4}$-inch wire rope, is indicated in the figure, the power being furnished by the gypsy head on a standard wide-drum logging engine. The carriage, which is 3 feet 6 inches by 4 feet 6 inches, has five 14-inch sheaves. The tree jacks, through which the standing line leads, have three 16-inch sheaves. The main line lead block has a 24-inch sheave. A 1-inch main line and a $\frac{5}{8}$-inch trip are used.

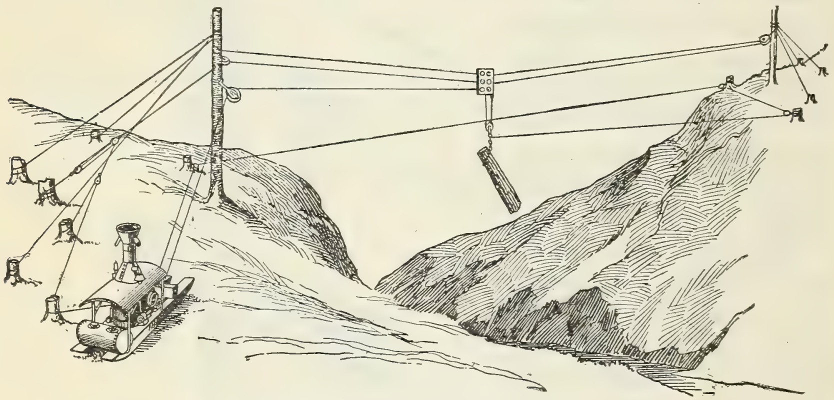

FIG. 52.—Double sky-line system.

The rig has worked successfully with a span of 2,200 feet, hauling logs scaling as high as 7,000 feet.

ROADING.

Under some conditions rather large bodies of timber are transported for long distances with ground logging engines, necessitating and justifying the use of pole roads. This is known as roading.

In the past it was the common practice in this region to road logs long distances to mills, drivable or towable waters, or railroads. At the present, however, roading is used only to a limited extent by loggers who are in a position to use the best methods, most of it being done in the Grays Harbor and Willapa Harbor regions. This is because the railroad, with the geared locomotive, has proved the better method. With railroad inclines and overhead logging methods perfected, long-haul ground logging will be used less as time goes on.

In the Grays Harbor and Willapa Harbor districts more logs have been, and are, driven than in all the rest of the Douglas fir region taken together. In many cases a pole-road haul of a mile or two delivers all the logs to a drivable stream, making roading a more satisfactory method of transporting logs than the railroad. Then, too, material satisfactory for railroad ballast is not infrequently scarce in the Willapa Harbor district. This, in connection with the fact that the rainfall is very heavy, makes the cost of railroad maintenance high and works in favor of the roading method in many cases.

METHOD.

While it is sometimes economical to haul logs 2,000 feet or more over a dirt road, as a general thing a fore-and-aft or pole road is built when the distance from the yarding engine to the railroad, stream, or mill equals or exceeds 2,000 feet. In the early days skid roads were used. This was the type of road used in connection with draft power, and it was natural for the logger to continue using it for a while with the logging engine. Some operators still build a part of the road of skids.

The logs are yarded, or yarded and swung, to these pole roads in the same manner as to railroads. They are then made into turns ranging from 6,000 to 12,000 feet, and hauled to the railroad, stream, or mill by a roading engine. One road engine may be ample, since under ideal conditions such an engine can haul logs for a little more than a mile. Not infrequently, however, a battery of road engines is necessary to haul the logs out of the woods, the rear machine taking the logs from the yarding engine and delivering them to the tail block of the succeeding road engine, and so on to the landing. It is seldom economical to employ more than two or three machines in a battery because of the cost for labor, wire rope, maintenance, etc. The general features of the road engine are the same as those of the simple-geared yarding engine, the striking difference being the rope capacity of the drums.

The main, or hauling, line is operated on the slack-rope principle, or in the same way as in ground yarding, with the road engine located at the landing and a heavy tail block swung a short distance above the yarding engine. The trip line, which is strung near the pole road in such a way that it will not interfere with the operation of the main cable, leads through trip blocks located at suitable points and then through the tail block, where it is attached to the woods-end of the main line. The main cable follows the road and is kept in place with blocks or rollers where turns are made.

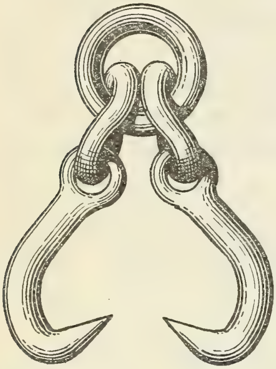
FIG. 53.—Coupling grabs.

From six to eight logs, depending on their size and the character of the road, are fastened one behind the other by means of grabs or dogs (figs. 53 and 54), forming turns, which are attached to the main cable. The turns are made up by a grab man. A chaser follows the logs to the landing, often riding in a rigging sled hollowed out of a log, which is attached to the rear log. He can signal to the road engineer at any point along the line by pulling on a wire which is stretched from the road engine. On arrival at the landing the chaser aids in placing the logs on the landing, removes the grabs from the logs, and returns with the grabs in the rigging sled to the yarding engine. In some cases, especially where the pole road is so steep in places that gravity causes the logs to run faster than the lines travel, the logs in the turn are not dogged up and pulled to the landing. Instead, they are pushed into the landing, a hook attached to the main line being made fast to the rear log. By this method several turns of logs of the ordinary size may be along the road at different points at one time.

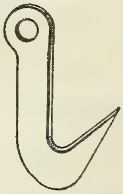
FIG. 54.—Logging dog.

It is practically impossible to say how far a road engine works on the average. Unless conditions are particularly favorable one machine will not be able to haul farther than 3,000 feet; in many cases less than this. At this distance a road engine should generally be able to handle the output of two yarding engines.

EQUIPMENT.

Road engines.—Simple-geared, wide-drum engines are used for roading, the size and drum capacities depending on the size of timber, character of road, and length of haul. They are mounted on sleds the same as ground yarding engines and moved over the ground from one setting to the other by their own power.

Lines.—The lines are the same size as those used in ground yarding, in some cases a little smaller. The trip line is roughly twice the length of the hauling line.

Grabs, dogs, and hooks.—Many kinds of equipment and methods are used to fasten the logs together in a turn. Ordinarily the logs are connected one behind the other with grabs or dogs. The grabs are made in different forms and the methods of using them differ somewhat. Figure 53 shows a pair of grabs, the cost of which amounts to $6 or $7. A pair of grabs is inserted in the end of each log, the grabs on the adjoining logs being connected with a short piece of cable. Some operators fasten the logs together with dogs of the type shown in figure 54. Two dogs are inserted in the end of each log on opposite sides, the short pieces of cable connecting the dogs of adjoining logs crossing each other in the form of an X. Dogs cost from $2 to $5 per pair. In some cases only the last two logs are dogged together, and the outer end of the main line is attached to the next to the last log with double chain grab hooks.

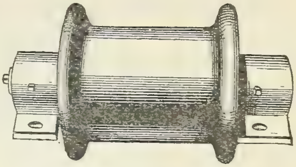

FIG. 55.—Road roller.

Blocks.—The number and type of blocks used in roading depend on the character of the road and the length of haul. In a general way, the same blocks are used in roading as in ground yarding. No large butt-chain lead blocks, however, are necessary.

Rollers.—When there are turns in the road, rollers are placed vertically on stumps or posts to keep the line leading with the load, to prevent wear on the cable, and to reduce friction. Rollers are also placed on the high points to prevent wear from downward pressure. Figure 55 shows one of the types of rollers used. The selling price in 1916 of this roller, smooth or corrugated, when made of manganese steel was as follows:

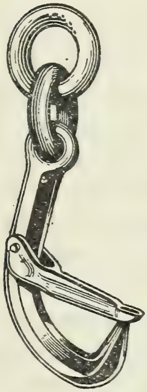

FIG. 56.—Road hook.

	Net selling price.
8 by 12 inch, with 2-inch shaft	$32
8 by 16 inch, with 2-inch shaft	36
10 by 16 inch, with 2½-inch shaft	40

Where the logs are pushed or kicked over the pole road instead of being pulled, a hook taking the form of the one shown in figure 56 is sometimes used. The guard lies back against the shank of the hook when the hook is in use, and automatically drops over the point of the hook when the hook is run back by the trip line, thereby protecting the point and preventing the hook from catching or hanging up when the line is run back. This hook costs from $13 to $17, depending on the size.

Miscellaneous equipment.—Practically all the differences in equipment between roading and ground yarding will be suggested by the peculiarities of the two methods, making it unnecessary to enter into a discussion of the miscellaneous equipment used in roading.

Special equipment.—When the road is so steep that the turn of logs runs, special devices are sometimes used.

(*a*) One of these, the cable grip, is shown in figure 60. At one camp where the grip is used the operator had to contend with the following conditions:

The topography of the country was such that the logs had to be hauled from one-half to 2 miles over pole roads by road engines. The aim was to secure a favorable grade of about 5 per cent. Too often the topography of the country was such that the grade in places was much steeper than this, amounting to 50 per cent at times. At one time two roads, each of which was from three-fourths to 1 mile in length, were used. One of these had a rise of 150 feet in the first 2,000 feet; from then on for a distance of 2,000 feet the rise was 550 feet, giving an average grade of 27½ per cent. A part of the road in the last stretch rose 350 feet in 1,000 feet, the grade for 300 amounting to 50 per cent. While the aim was to make the roads as straight as possible, it was necessary to put in curves to cheapen the construction cost.

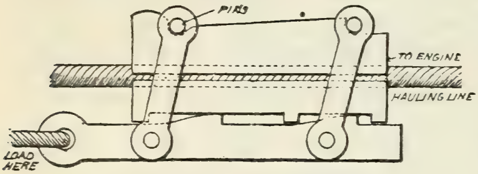

FIG. 57.—Road cable grip.

About 100,000 feet of timber per day was hauled over this pole road. This output, however, only indicated the possibilities of the method under these conditions; considerably more, without doubt, could have been handled. On another road, which was about 1¾ miles in length and had grades equally bad, a little more than six trips per day were made, 15 logs, having an average volume of 1,200 feet, being taken at a turn.

The success of these long hauls was attributed to the cable grip (fig. 57), by means of which the turn of logs is attached to the hauling line. It consists of two jaws which have a gripping action when the strain of the load is brought to bear on it. This action automatically clamps the line between the jaws with sufficient force to haul the load. Whenever the load starts to travel faster than the line, the jaws are released, permitting the grip to slide along on the hauling line. Because of this the lines are not snarled and blocks are not torn down, neither is there the amount of line breakage that would occur under other conditions, since when the load slows down the grip takes hold gradually, the result being that the load does not stop. This continuous movement of the load could not be secured if the load were fixed rigidly to the line or if the load were attached to the line with a sliding ring, which would be engaged by a "bull ring" on the end of the line when the load was picked up.

(*b*) Another device (fig. 58) is used with an endless line to snub logs down steep chutes. The endless line is wound around the two 42-inch drums—one grooved for four turns, the other for five—four times in the form of a figure "8." It is operated by means of one lever, which keeps the line from slipping and enables the two brakes to hold the line in control on any grade. Two rings are fastened to the snubbing line, which is strung along the road, one at the machine, the other at the tail block at the bottom of the hill. One company used this device to lower logs a drop of 500 feet in one-half mile, some of the grades being nearly 40 per cent. The logs were hauled over a pole road by a road engine for a distance of 1 mile, the turns averaging six logs. At the head of the sharp incline the turn was stopped opposite the snubbing machine and fastened to the snubbing line. A man took his place at the brake of the snubbing machine, the signal was given, and the road engine started the turn down the chute, the man at the machine regulating its speed down the hill and stopping it at the bottom. The machine costs about $600.

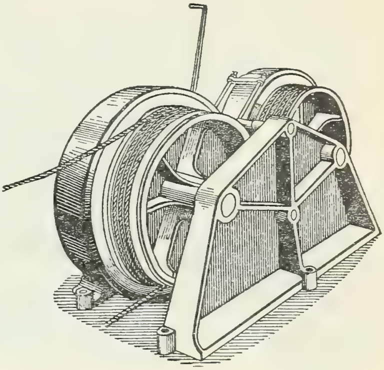

Fig. 58.—Snubbing device.

Several other types of snubbing machine are used. Figure 59 shows the method of using a compressed-air snubbing machine.

IMPROVEMENTS.

The improvements in the main consist of pole roads or chutes, which, in short, are troughs formed by laying two or more strings of logs side by side on the ground or on sills. These require a right of way from 12 to 14 feet wide, which is swamped out carefully and graded to avoid abrupt changes. It is better to make cuts than fills, since a more solid foundation is thus secured.

Fore-and-aft roads may be constructed on almost any grades. The usual grade of a downhill road ranges from 5 to 25 per cent. Grades of 30 per cent or more, if of considerable length, are likely to lead to trouble through the logs running and jumping out of the road. Adverse grades may and do occur in these roads, although it is preferable to keep the adverse grades down to 10 or 15 per cent.

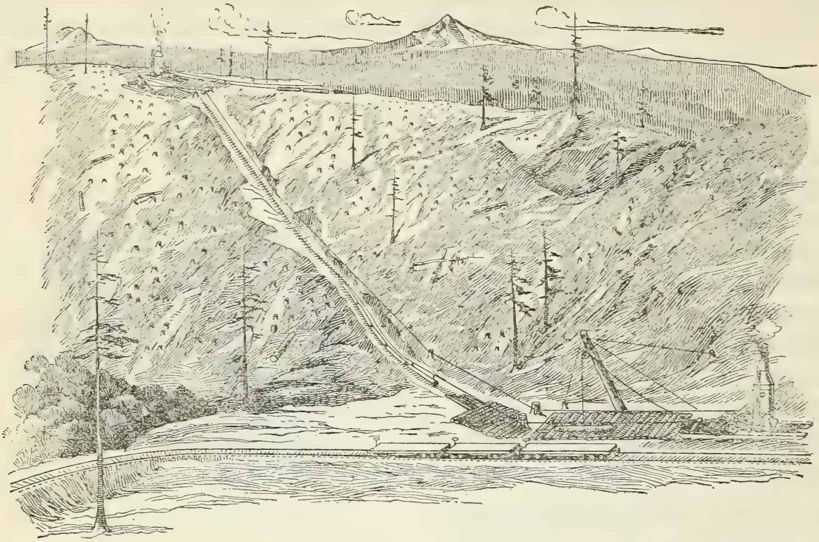

FIG. 59.—Method of using compressed air snubbing machine.

Roads having adverse grades of 40 or 50 per cent have been used. An engine is generally required at the top of any long or very steep adverse grade.

The best results are obtained from straight roads, because curves increase the friction, reduce the hauling ability of the engine, cause greater wear on the cable, make it difficult to keep the logs in the road, increase the maintenance cost of the road, and curtail the output. Curves, however, are necessary in many cases to change the general direction of the road. Short curves or reverse curves are out of the question, and usually not more than two or three curves are practicable, even in the longest roads. A change of 90 degrees in the direction of a road may be made by means of two long and gradual curves.

In constructing the roads the ends of the logs are joined together, the tops being placed in the direction in which the logs are hauled. In the case of a two-pole road the logs are placed from 6 to 8 inches apart, the inner sides being hewed in such a way as to form a trough 10 inches wide at the bottom and 30 inches wide at the top. Cross skids, placed at 10-foot intervals, are used to support the road across depressions, and braces are used to prevent spreading. Where the road is embedded in the ground skids and braces are not necessary except at the joints. Where possible inferior species are used as construction material, the logs being 60 or 70 feet long and from 14 to 30 inches in diameter at the top. In some cases a wider road is necessary or preferred, making the use of three or more strings of logs necessary. Two logs are placed in much the same way as above, and a third log embedded in the ground between them. The outside logs are from 14 to 30 inches in diameter at the top, the bottom log a little smaller.

The labor cost per linear foot for these improvements ranges from $0.25 to $0.50 for a pole road, and from $0.50 to $0.75 for a chute road. One operator is of the opinion that pole roads can be constructed at a labor cost of $0.30 per linear foot; chutes at a labor cost of $0.50 per linear foot. In one case the labor cost of building 1,000 feet of pole road amounted to $250, which is at the rate of $0.25 per linear foot. The road was constructed on steep, side-hill ground and consisted of two strings of logs. Two small canyons had to be crossed, which required two spans of 100 feet each. Two logging engines, working toward each other, were used, the time required to complete the stretch of road amounting to six days.

COST.

It is not practicable to deal with the cost of roading per thousand feet except in a very general way, since the work is carried on under so many different conditions.

Labor cost.—A road-engine crew is usually made up of an engineer, fireman, wood buck, chaser, and grab man. When the roading engine is hauling from two yarding engines, an additional grab man is employed. The wages paid the crew are discussed under "ground yarding."

The average operating labor cost per thousand feet ranges from 10 to 50 cents, depending for the most part on the amount of timber transported over the road to the landing and on the number of roading engine crews used. To illustrate the effects of natural conditions on roading costs, the following hypothetical statement is given. It is based on the assumption that a road engine is hauling 3,000 feet, that the output of two yarding engines is hauled to the landing, and that the output of the yarding engines varies with the size of the timber.

Hypothetical statement showing the effect of output on the operating labor cost per thousand feet for roading.

Volume of average log.	Roading output per day.	Labor cost per thousand feet.
Feet.	*Feet.*	
2,000	180,000	$0.11
1,750	155,000	.13
1,500	135,000	.15
1,250	125,000	.16
1,000	110,000	.18
750	90,000	.22

The labor cost per 1,000 feet would have been twice as high if it had been based on the output of one yarding engine instead of two. The same thing would have happened if the cost had been based on the use of two roading engines instead of one. If the cost had been based on the assumption that two roading engines, working tandem, would handle the output of one yarding engine, it would have been four times as high.

Wire rope.—The cost of wire rope per 1,000 feet is rather heavy, nearly equaling in some cases the operating labor cost. An average cost would serve no practical purpose. From the standpoint of a timber appraisal, it is safe to figure that the hauling line will handle 10,000,000 feet; the trip line, 15,000,000 feet. The lines used vary somewhat in diameter. As a rule, however, the main or hauling line is made of 1¼-inch rope; the trip line of five-eighths inch.

Maintenance and depreciation of roading engines.—Roading engines are not subject to so much strain as ground yarding engines. And as they are of the simple-geared type, they are not so complicated in make-up. This results in a lower maintenance cost. It also tends to give roading engines a little longer life than the compound-geared yarding engines. The maintenance cost of logging engines, also the amount that should be written off annually for depreciation, is discussed under "Ground yarding."

Improvements.—The cost of pole roads per thousand feet ranges from 20 to 50 cents, the amount in a specific case depending on the total cost of the road and the volume of timber hauled over it.

Other costs.—The cost of fuel, blocks, hooks, rollers, lubricants, waste, and packing for roading is practically the same as for ground yarding.

LOADING.

METHODS.

A number of methods are used in loading logs on railroad cars or trucks. Here, as in other departments of the logging operation, personal ideas of operators conflict to some extent. A method that satisfies one superintendent under certain conditions might not satisfy another. There is no disagreement, however, as to what in a general way constitutes a proper method, since all agree that it should be adapted to the conditions; that it should facilitate and not delay yarding; and that it should do the work at a minimum cost.

PARBUCKLE METHOD.

Logging jacks in connection with skids or landings were first used to load logs in the region. This method, being slow, was soon superseded by the parbuckle method, which resembles the cross-haul method of the East. The parbuckle method is still extensively used in the Grays Harbor country. One hundred thousand feet of timber per day can be loaded satisfactorily with it where the logs average 2 or 3 feet in diameter and 40 feet in length. It requires a more elaborate and costly landing than other loading methods.

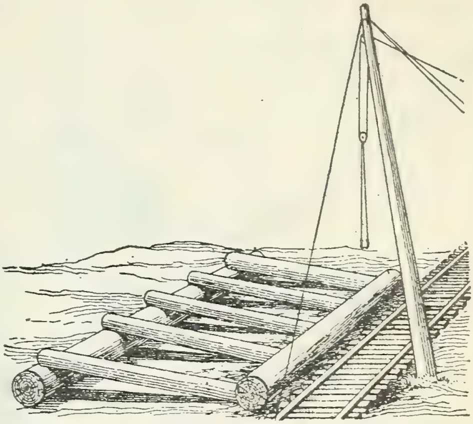

FIG. 60.—Common type of deck landing.

A gin pole is erected on the side of the track opposite to the landing, to which a single sheave loading block is attached about 30 feet from the ground. The loading line, leading from the drum that furnishes the power, passes through the loading block, then around the logs to be loaded, and thence over the car to the base of the gin pole where it is hooked. When the power is exerted on the line the log is rolled from the landing to the car.

SINGLE GIN-POLE METHOD.

In many cases the loading rig consists of a single gin pole about 60 feet in height, a main loading line, crotch lines, and hooks, tongs, or slings, the power being furnished by a loading drum on the roading or yarding engine or by the main drum of a separate loading engine (fig. 60). The gin pole is erected on the side of the track opposite the landing and just far enough from the track to permit the passage of cars, and with the top, or the part to which the rigging is hung, over the center of the track. A 1-inch main loading line, leading from the engine, passes through a 14 by 2 inch corner block at the top of the gin pole, and then down to the log. Two lines, called crotch lines, from 25 to 30 feet in length, depending on the length of the logs and whether loading hooks or tongs are used, are attached to the end of the main loading line. The crotch lines are attached to the logs by means of hooks, tongs, or slings (figs. 51, 61, and 62). Where more power is necessary because of the size of the logs, a 14 by 2 inch fall block in addition to the corner block is used (fig. 60). In such cases, the main loading line, generally seven-eighths inch in diameter, passes through the corner block, then through the fall block, and thence to the top of the gin pole, where a "tail hold" is taken.

This method followed the parbuckle method, and was very generally used. The last three or four years it has been giving way to overhead loading methods. It requires landings (of the type shown in fig. 60), which is its most objectionable feature. Landings adapted for this method must be made small because of their cost, and so afford insufficient storage space. This method is not so fast as overhead methods, neither does it allow the loaders the privilege at all times of deciding the order in which the logs shall be loaded.

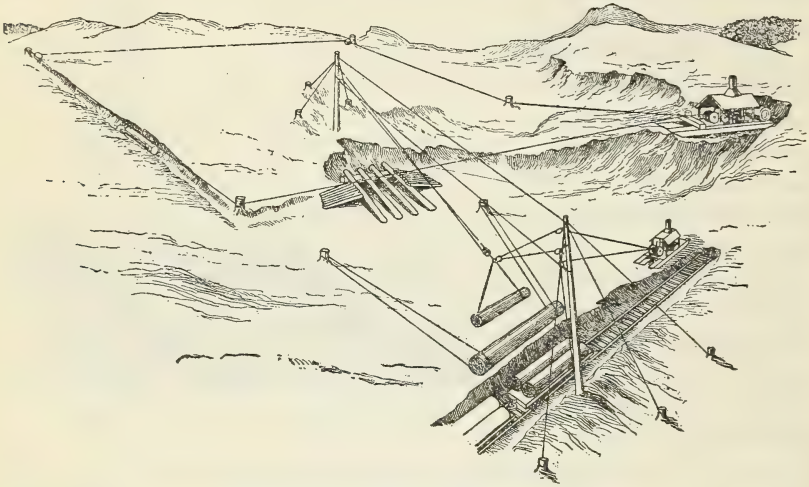

FIG. 61.—Overhead loading system.

The fixed investment in equipment at one side with this method, where the power is furnished by a separate loading engine and no fall block is used, amounts to about $2,718, as follows:

1 7 by 10 inch double-drum loading engine	$1,625
1 set of guy lines	100
1 main loading line	85
1 spotting line	45
3 14 by 2 inch loading blocks	63
Loading-engine repair parts and materials	75
Loading-engine sled	250
Oil-burner equipment, including oil and water tank	375
Miscellaneous equipment	100
Total	2,718

The statement includes equipment in use as well as on hand.

If a fall block is used, the fixed investment will amount to $2,739. If a fall block is used and the power is furnished by a loading drum rather than by a separate loading engine, the fixed investment will amount to about $500, the cost of the loading drum amounting to $150.

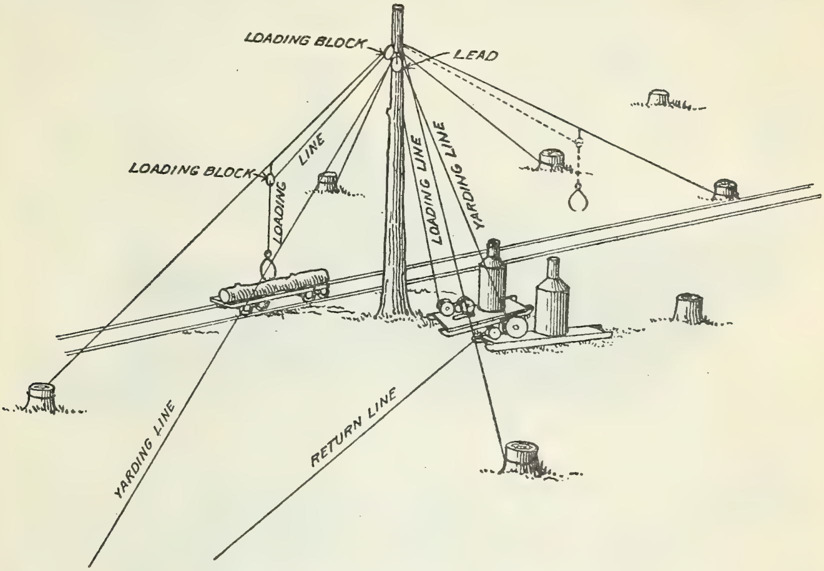

FIG. 62.—Single guy-line loading system.

OVERHEAD METHODS.

In the last few years overhead loading systems have been adapted to coast timber. These systems, while varying considerably in details, are based on two rather distinct principles:

(1) One overhead loading system has no standing line (fig. 63). It has two wire-guyed gin poles, which are from 100 to 200 feet apart. The head pole is about 60 feet in height and erected on the side of the track opposite the landing. The tail pole is from one-fourth to one-third the height of the head pole and placed back of the landing. Occasionally it is possible to use a high stump for a tail tree. The $\frac{7}{8}$-inch main or hoisting line leading from the main drum of a separate loading engine is reeved through a double-sheave corner block suspended at the top of the head pole and a single-sheave fall block hung in the bight of the line, the tail hold being taken on the fall block. Another line, the trip line, about five-eighths inch in diameter, leading from another drum on the engine, passes through a 12 by 2 inch corner block at the top of the

head pole, then through another block of the same size on the tail pole, and thence to the fall block of the hoisting line, where it is attached. With crotch lines attached to the fall block, the largest logs can be lifted from the landing and moved toward or away from the car.

In one case, the power is furnished by a 9½ by 10 inch double cylinder engine, steam being supplied by a 50 by 120 inch vertical boiler, having a working pressure of 175 pounds. The upper or main drum carries the hoisting line. On the front shaft are two drums, one of which carries the trip line, the other the straw line. By means of the straw line, cars can be moved at the pleasure of the engineer, the power furnished being ample to "spot" six loaded cars on a 2½ per cent grade. The three drums are operated by three separate friction devices, making them independent of each other. The car and the load are under the control of the loading engineer at all times. The load is lowered by means of a powerful steam brake, thus eliminating the danger of dropping a log, which might injure a loader or break a car.

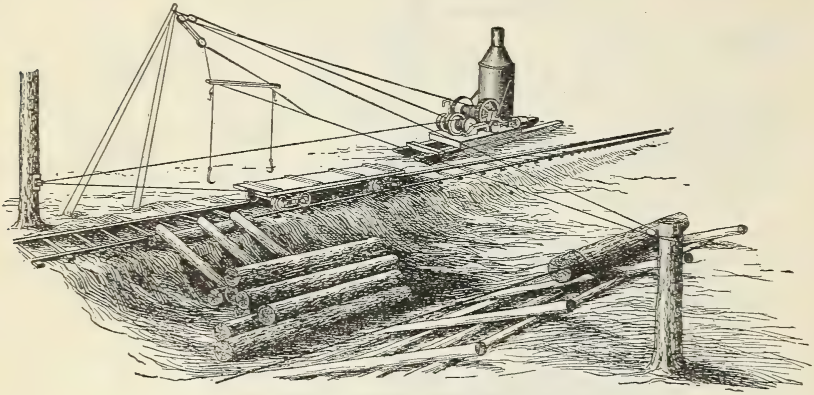

FIG. 63.—Overhead loading system.

In some cases the ⅞-inch hoisting line, leading from the main drum, passes through a 14 by 3 inch single-sheave corner block at the top of the head pole, then through a fall block of the same size, and thence to the gin pole, where a tail hold is taken. The scheme is shown in figure 61. In other cases, one of the trip-line corner blocks is hung on a 1¼ or 1⅛ inch guy instead of a tail tree, the guy line, which is called the front guy line, being strung from the top of the head pole to a stump at the back of the landing. The scheme is shown in figure 64.

The fixed investment in equipment at one side with this method, when a double-sheave corner block is used, is about $4,193, as follows:

1 9 by 10 inch three-drum loading engine	$2,825
1 set of guy lines	100
1 main loading line	140
1 trip loading line	100
1 spotting line	45
2 double-sheave blocks	120
2 single-sheave blocks	63
Loading engine, repair parts, and materials	75
Loading engine, sled	250
Oil-burner equipment, including oil-and-water tank	375
Miscellaneous equipment	100
Total	4,193

NOTE.—The statement includes operating equipment as well as equipment on hand.

In many cases two sets of crotch lines, a spreader, and a set of loading lines (figs. 63 and 64) are used instead of one set of crotch lines, the spreader giving the engineer much better control of the log when it is in the air than the unmodified crotch line device (fig. 61), because it checks the tendency of the log to swing back and forth several times before it can be lowered to its position on the car. The spreader is about 12 feet long and is made of 45-pound railroad iron. The crotch lines are attached to the ends of the spreader by means of $1\frac{1}{4}$-inch clevises, the crotch of the upper or hoisting set being about 8 feet from the spreader, the crotch of the trip set about 10 feet from the spreader. The loading lines are about 18 feet long, which is ample for logs up to 40 feet in length. Attachments are used for longer logs. This device increases the fixed investment about $50.

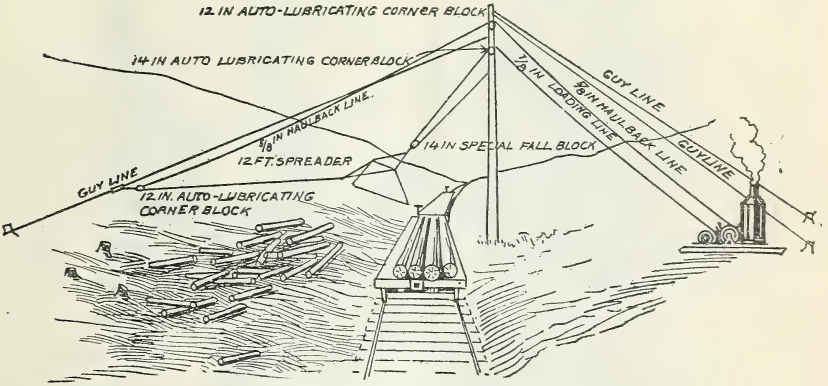

FIG. 64.—Overhead loading system.

With this system the landing place can be made very wide, sometimes 150 or 200 feet, since few or no landing improvements are necessary. No yarding time is lost because of blocked-up landings; 100,000 feet or more of logs can be stored, so that the yarding crew can continue at work after the loading crew has been forced to stop

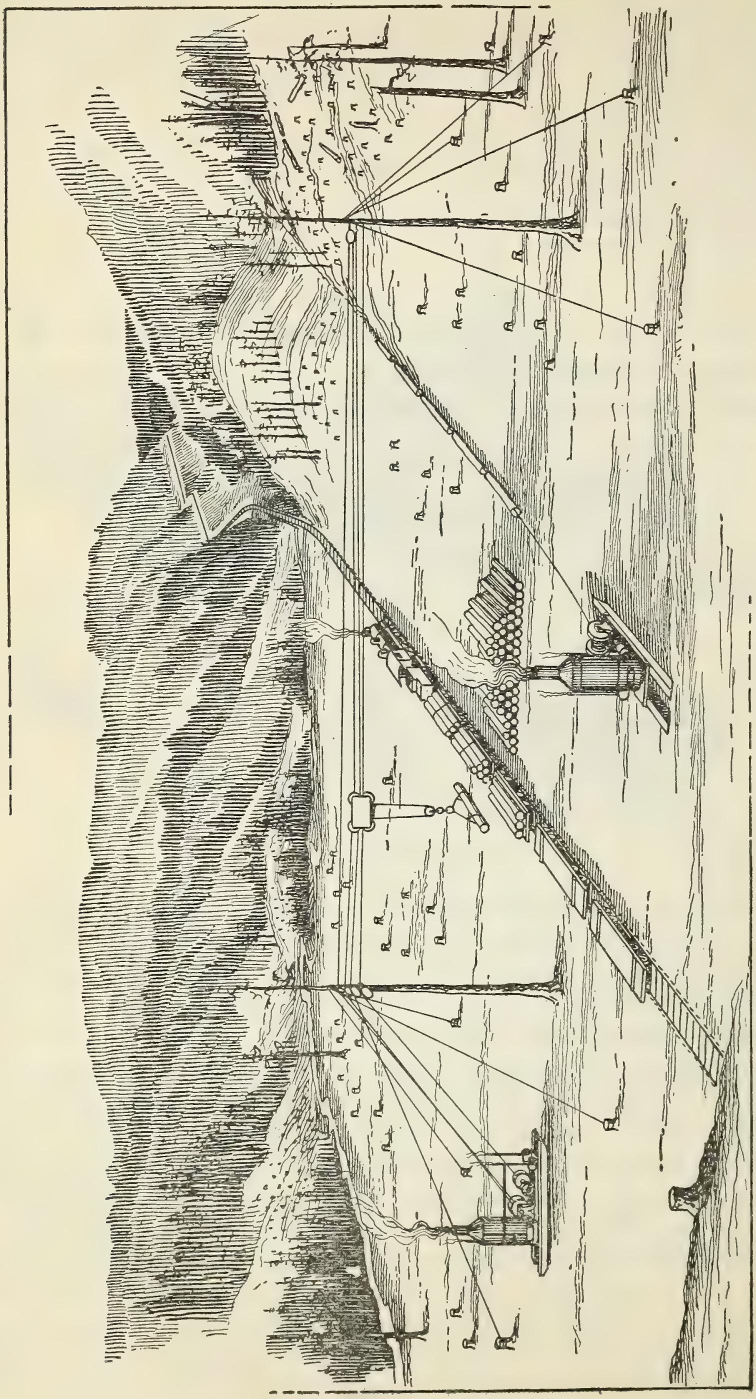

FIG. 65.—Overhead loading system.

because of a breakdown in the loading or railroad department. The system enables the loaders at all times to select the most desirable logs from the standpoint of making up a carload, which can not be done with the single gin-pole method. Furthermore, better settings can be secured for the yarding engines. In one instance the logs were yarded in on one side of a ravine, while the railroad and loading engine were operated on the other. The bottom of this ravine was about 30 feet below the level of the track, providing storage space for more than 600 logs. The largest yarding output can easily be handled with this method. Landings may or may not be used. Some operators feel that they are essential because they protect the cars and facilitate ground yarding. In any case they are simple in construction (fig. 61).

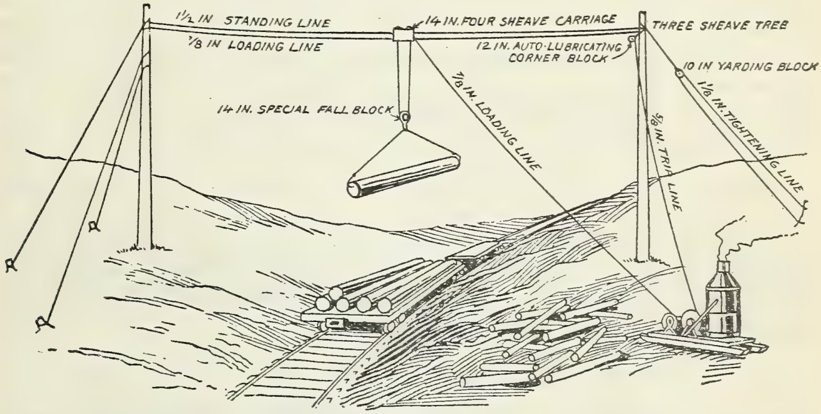

FIG. 66.—Overhead loading system.

(2) A standing line is used with the other type of overhead system (fig. 65). Two well-guyed trees or gin poles are used, one on each side of the track. These can be anywhere from 200 to 800 feet apart, the distance depending on the chance, and so located as to permit the loading of logs from either side of the track at one setting. A 1½-inch standing line is stretched taut from one pole to the other at from 40 to 60 feet from the ground. A 14-inch four-sheave carriage, riding the standing line, can be racked in either direction at a speed of about 800 feet per minute by two three-fourths inch trip lines. The trip lines, leading from opposite ends of the carriage, pass through 14 by 2 inch corner blocks suspended at the top of the gin poles to the two upper drums of a three-drum, four-cylinder loading engine. The seven-eighths to 1 inch main or lifting line, leading from a tail hold on one of the gin poles, passing through the two lower sheaves of the carriage, looping down and supporting a 14 by 2 inch fall block in the bight of line, then through a 14 by 2 inch

corner block on the other gin pole, and thence to the lower drum of the engine. The lifting line is handled independently of the trip lines, making it possible to raise or lower the load while the carriage is running on the standing line.

The fixed investment with this method varies considerably, depending for the most part on the distance between the spar trees. It would seem that it should never exceed $5,337 at one side, as follows:

1 four-drum loading engine	$2,700
2 sets of guy lines	200
1 standing line	550
1 14-inch four-sheave carriage	150
2 trip lines	330
1 loading line	300
7 14 by 2 inch blocks	147
2 tree shoes	60
1 spotting line	100
Loading-engine repair parts and materials	75
Loading-engine sled	250
Oil-burner equipment, including oil and water tank	375
Miscellaneous equipment	100
Total	5,337

Where it is desired to load on only one side of the track at a setting, only one trip line is used. The scheme is shown in figure 66. Under such conditions the fixed investment should not exceed $4,900, since the cost of blocks and trip line is less.

GUY-LINE METHOD.

The guy-line method of loading is not infrequently employed with overhead and high-lead yarding methods, for which it is particularly adapted. As a rule, the head spar tree used with these yarding methods is guyed with from 6 to 11 lines, 2 of which can be so arranged as to permit the attachment of a loading block at a point directly over the center of the track and about 60 feet from the ground (fig. 62). The loading line, leading from its drum on the loading engine, passes through a block on the head spar tree, thence through the loading block suspended to one of the loading guy lines. In some cases the latter block is attached to a loading carriage, which in turn is supported by the loading guy line. A pair of tongs is attached to the loading line, the weight of which is sufficient to prevent the loading line from running back through the block. Where the yarding and loading engines are mounted on separate sleds the location of the loading engine, as related to the location of the yarding engine, depends on the chance. The yarding and loading engines may be placed side by side on the same side of the track, as near the foot of the head spar tree as possible, with the loading engine next to the track, the logs being loaded directly to the cars from the point of delivery of the yarding engine. In many cases the loading engine is mounted on the same sled or car as the yarding engine, the combination machine being set as close to the head spar tree as possible.

When the yarding output is large, this method is not entirely satisfactory, since the logs can not be loaded with it as fast as they are yarded. In an attempt to remedy this condition and still use practically the same method, some operators are using two loading lines instead of one (fig. 34). The two lines lead from the loading engine and pass through blocks suspended on guys immediately over the car to be loaded, in the same manner as in the case of the single loading line method. One loading engine designed especially for this method consists primarily of two independent loading engines mounted on a common frame. The drums are fixed to the shaft and can be operated in the same direction or opposite directions at the same time, being controlled by two throttle levers. The cylinders are 9¼ by 10 inches. The loading engine is mounted on a 125,000-pound capacity car, immediately in front of the yarding engine. The yarding and loading engines and car form a complete yarding and loading unit, somewhat similar to the tree-rigged Lidgerwood overhead skidder. It is not necessary, of course, to mount the loading and yarding engines on a car. Certain advantages, however, result from this arrangement, such as the saving of time when moving, and the elimination of a loading fireman, the loading engine taking its steam from the same boiler as the yarding engine. When operators are properly equipped to get the most out of this equipment, the loading and yarding engines are mounted on a steel car with swivel trucks, the swivel trucks making it possible to set the car to one side of the track without constructing a siding.

The fixed investment in equipment with this method at one side, where two loading lines are used, amounts to about $4,420, as follows:

1 9¼ by 10 inch Duplex loading engine	$3,000
2 loading jacks	120
2 loading guys	225
5 blocks	110
2 loading lines	120
1 spotting line	45
Loading engine repair parts and materials	75
Loading engine sled	250
Oil burner equipment, including oil and water tank	375
Miscellaneous equipment	100
Total	4,420

NOTE.—The statement includes operating equipment as well as equipment on hand. Duplex loading engines without boiler cost from $2,200 to $2,400. A steel car costs about $2,000; with air brakes, $2,200.

SWINGING BOOM LOADING DEVICE.

It has been found in handling medium to small-sized logs in heavy stands with the Lidgerwood tree-rigged skidder that not infrequently more logs can be yarded than can be loaded with the guyline loading method. To remedy this defect some operators are using a swinging boom of the type shown in figure 67.

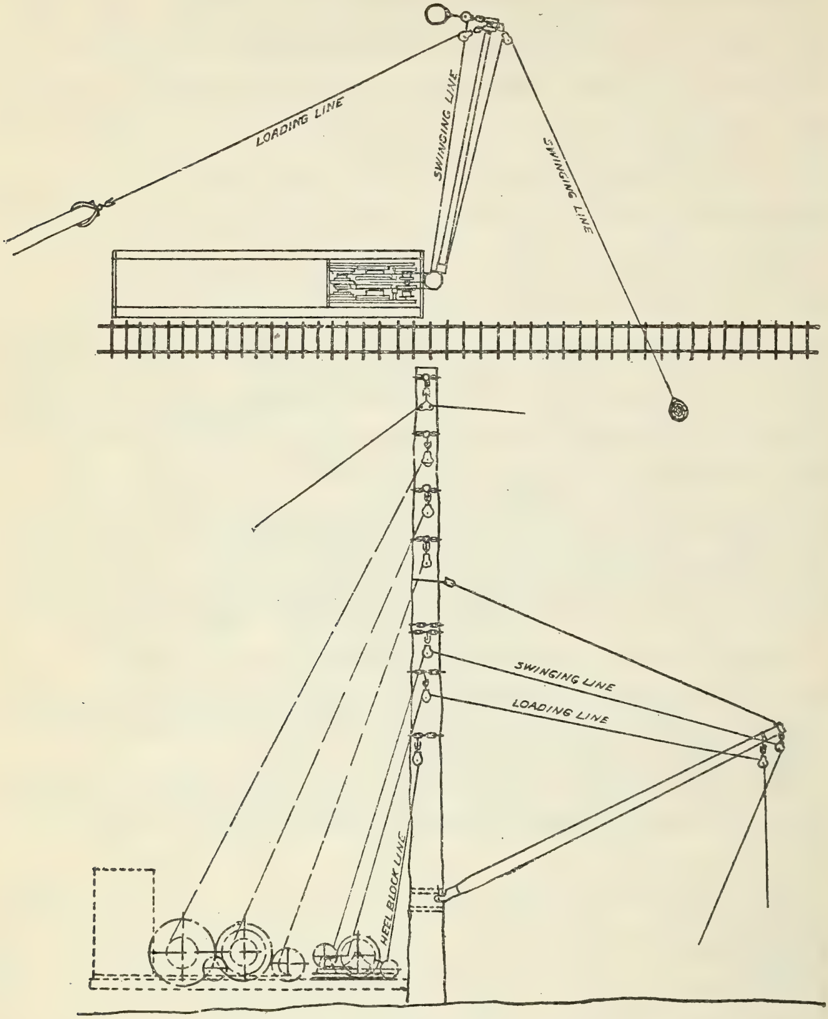

FIG. 67.—Swinging-boom loading system.

The boom is about 50 feet long and made of a 16 by 16 inch timber, tapered down to 12 by 12 inches at each end. The end that is attached to the head spar tree is stepped on the under side, and has a hole about 1 inch larger than the pin. It is fastened to the tree by two 2-inch eye bolts.

This method is used in connection with a six-drum loading engine. One of the two drums nearest the spar tree carries the heel block or tightening-up line; the other, the transfer line. One of the two large middle drums carries the loading line; the other, the train or "spotting line." The other two drums carry the swinging lines. The efficiency of the whole device depends largely on the proper rigging and handling of the last-mentioned line. When loading is being done from the left side, the line from the left swinging drum should lead through a deep sheaved block attached to the left side of the spar tree and somewhat above the peak of the boom, thence to a block attached to the left side of the outer end of the boom, and thence to a stump opposite the swinging drum and from 40 to 60 feet from the engine. The opposite line is rigged in a similar manner.

It is claimed that this rig will load logs averaging 700 feet in volume at the rate of one per minute or minute and a half, and that it is especially valuable for loading from steep ground.

EQUIPMENT.

LOADING ENGINES.

The power used in loading may be furnished by a loading drum on the yarding or roading engine, or by a separate loading engine. In times past it was the universal practice to use a spool or loading drum on the yarding or roading engine; that is, when power machinery was used in loading. For several years, however, a number of operators have used a separate engine in loading. With the single gin-pole loading method, it is difficult to load the logs as fast as they are yarded when the power is furnished by a loading drum on the yarding engine, or at least in such a way and at such times as not to interfere with the yarding work. The use of a separate loading engine is thought to be safer, since the engineer has only the loading to occupy his attention. It is not possible to use the loading drum on a yarding engine with overhead loading engines.

The cylinders of loading engines range in size from 6½ by 8 inches to 9½ by 10 inches. The engines are built with one, two, three, or four drums. On most types there is a gypsy on the extended drum shaft. All loading engines have steel frames, high or double high pressure boilers, and liberal friction drums with brakes, pawls, etc.

The single-drum engine is adapted for use with the single gin-pole loading method. The double-drum engine is designed for use with overhead loading methods that do not require a standing line. The three-drum engine is used to operate the same sort of overhead system. When the third drum is not needed for loading purposes, it may be employed to good advantage in switching and spotting cars. The four-drum engine is adapted for operating a system of loading that uses a standing line upon which a carriage travels.

In connection with the following discussion of prices and weights, the sizes of most of the loading engines used in the region are given. It will be noted that there is no great range of sizes. The larger sizes are, of course, used in loading the larger timber. The tendency of the industry is to use large loading engines. The sizes used in connection with different loading methods are suggested under "Methods."

The selling prices of loading engines are given in Table 23. The prices are those of March, 1916, and it can not be said that they are more than substantially correct for that time, since they were furnished by manufacturers to be used in this publication and not for the purpose of trading. The prices are on standard engines and do not include any special parts.

TABLE 23.—*Sizes, weight, and prices of loading engines.*

Size.	Type.	Capacity of drums.	Size and working pressure of boilers.	Speed of lines.	Weight.	Selling price f. o. b. Portland, Tacoma or Seattle.
Inches.				*Feet per minute.*	*Pounds.*	
6½ by 8	Twin-drum.	500 feet ¾-inch line 780 feet ⅝-inch line	36 by 84 inches high, 150 working pressure.	275	4,300	$1,125
6½ by 9	Double-drum.	Lower, 1,050 feet ¾-inch line Upper, 1,050 feet ¾-inch line	36 by 84 inches high, 150 working pressure.	Lower, 300 Upper, 425	9,100	1,240
7 by 10	Single-drum.	1,650 feet ¾-inch line 2,340 feet ⅝-inch line	42 by 84 inches high, 150 working pressure.	270	8,100	1,295
7 by 10	Single-drum.	2,580 feet ¾-inch line	44 by 106 inches high, 175 working pressure.	400	11,000	1,250
7 by 10	Double-drum.	Main, 2,580 feet ¾-inch line Trip, 2,580 feet ¾-inch line	44 by 106 inches high, 175 working pressure.	Main, 340 Trip, 400	14,800	1,625
7 by 10	Three-drum.	Main, 2,580 feet ¾-inch line Trip, 1,480 feet ⅝-inch line	44 by 106 inches high, 175 working pressure.	Main, 400 Trip, 400	16,400	1,800
7 by 10	Four-drum.	Main upper, 1,480 feet ⅝-inch line. Trip upper, 1,480 feet ⅝-inch line. Main lower, 1,480 feet ⅝-inch line. Trip lower, 1,480 feet ⅝-inch line.	44 by 106 inches high, 175 working pressure.	Main, 400 Trip, 400	17,500	1,900
7¼ by 10	Three-drum.	Main, 1,200 feet ¾-inch line Trip, 350 feet ¾-inch line	42 by 84 inches high, 150 working pressure.	Main, 293 Trip, 383	11,000	1,745
9 by 10	Three-drum.	Main, 1,740 feet ⅞-inch line Lower, 830 feet ¾-inch line	48 by 103 inches high, 175 working pressure.	Main, 376 Lower, 470	25,500	2,825
9½ by 10	Three-drum.	Main, 1,100 feet 1-inch line Trip, 1,890 feet ⅝-inch line Car drum, 1,180 feet ⅝-inch line.	50 by 120 inches high, 175 working pressure.	Main, 370 Trip, 440 Car, 440	24,000	2,675

It was pointed out in the discussion of yarding that some operators use an extra yarding engine for the purpose of reducing the time lost in moving from one setting to another. This means that such operators have an extra loading engine also if the power used in loading is furnished by a separate loading engine.

LOADING ENGINE REPAIR PARTS AND MATERIALS.

For the purpose of a timber appraisal the fixed investment in loading engine repair parts and materials in connection with one engine may be placed at about $75.

SPARK ARRESTERS, WATER TANKS, SLEDS.

The selling prices of spark arresters are given under the heading "Ground yarding." Steel tanks adapted for use in connection with loading engines cost about $100. Loading engine sleds cost about $200 and last from three to four years. Spark arresters, water tanks, and sleds are discussed under the heading "Ground yarding."

OIL-BURNER EQUIPMENT.

The approximate cost of the equipment used in burning crude oil on loading engines amounts to $375. This price includes the tank on the rear end of the sled, which is used for the storage of both oil and water. The cost of the maintenance of this equipment amounts to about $25 per year.

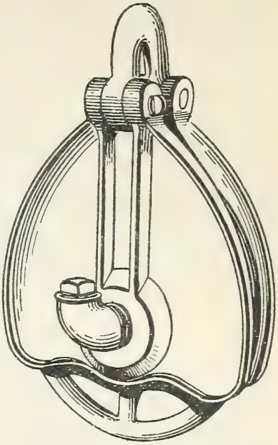

FIG. 68.—Loading block.

BLOCKS.

Only such blocks as are used in loading are taken up here. Some of the blocks listed under this heading, however, are used in overhead and high-lead yarding.

Figures 68 and 69 show two of the types of loading blocks. Several other types are used. The proper size of blocks was discussed in a general way under the heading "Ground yarding." The size to be used with different methods of loading is suggested in the discussion headed "Methods."

The cost of loading blocks varies because of difference in the type, size, and make, and because different materials are used in their construction. The following gives the weight, size, and selling price of two types of loading blocks, f. o. b. Portland in March, 1916. It should be borne in mind that blocks are manufactured by several companies and that they can no doubt be purchased as satisfactorily at Tacoma, Seattle, and other points as at Portland.

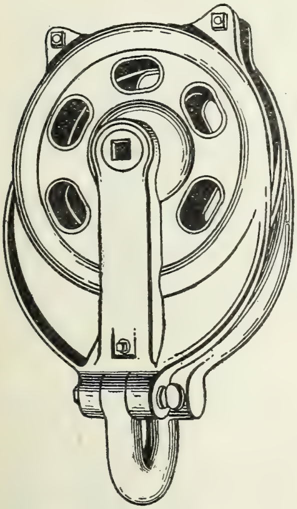

FIG. 69.—Overhead block.

	Net price.
No. 1 sheaves, 12 by 1½ inch manganese steel	$18
No. 2 sheaves, 14 by 1½ inch manganese steel	22

This block is adapted for gin-pole or overhead loading.

The blocks listed below are adapted for any work where blocks are hung in an overhead position and frequent oiling is impossible without great loss of time. They are of the auto-lubricating type. The sheaves are made of manganese steel.

Prices of blocks.

No.	Sheave.	Bearing.	Diameter pin.	Weight.	Net price.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	
1	12 by 2	3	2½	115	$27.00
2	14 by 2	3	2½	150	34.00
3	18 by 2½	4½	3	230	50.00
4	24 by 3	5	3½	410	81.00
5	24 by 5	7	3½	450	90.00
6	36 by 3	8	3½	750	144.00

TREE JACK.

Figure 46 is a cut of one of the types of tree jacks. They are designed for extremely heavy duty, such as is found in overhead loading and yarding. They are easy on the lines, since the strain is equally divided on the three sheaves, the same results being secured as with an extremely large sheave. The size and net selling prices f. o. b. Portland, Tacoma, or Seattle in March, 1916, were as follows:

Tree jacks.

No.	Size of sheaves.	Net selling price with manganese-steel sheaves.
	Inches.	
1	10 by 3	$67.50
2	14 by 3	78.75
3	16 by 3	90.00
4	9 by 7	82.50
5	14 by 6½	93.75
6	16 by 9	114.00

Spares.

Item.	Net price.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Pair forged sides	$22.50	$25.50	$27.00	$22.50	$25.50	$27.00
Bronze bushed manganese-steel sheaves	9.75	13.50	15.00	15.00	18.00	24.00
Shackle and pin	5.25	6.00	6.00	5.25	6.30	6.80
Set of three pins	6.80	6.80	7.30	6.80	8.00	9.00
Bronze bushing	2.65	2.65	2.65	3.40	3.75	5.25

LOADING LINES.

The selling price of wire rope is discussed under "Ground yarding." The length and size of lines used are dealt with under "Methods" in this section.

MISCELLANEOUS EQUIPMENT.

In addition to the equipment listed above, some small equipment is necessary in connection with loading, such as hooks, tongs, slings, straps, splicing tools, links, engine repair tools, clevises, etc. The fixed investment in such equipments amounts to about $100 per loading engine.

COST.

The cost of loading consists, in a general way, of operating labor, improvements, depreciation on loading engines, maintenance or replacement of lines, blocks, etc., and supplies. Some operators consider it advisable to charge a portion of certain more or less fixed costs, such as the salaries of foreman, bookkeeper, timekeeper, etc., to loading.

OPERATING LABOR.

The operating labor constitutes the heaviest item of expense. It is this item which generally finds its way into cost statements of operators under the heading "Loading." Needless to say such a segregation is misleading unless one is familiar with the practice.

The total cost of a loading crew per day depends on the method used and the rate of pay. If the power is furnished by a spool on the yarding or roading engine, the loading crew is usually considered as being made up of a head loader, second loader, and spool tender. In theory, a part of the labor cost of the fireman and wood buck, necessary adjuncts of the yarding or roading crew, should be charged to loading. If the power is furnished by a separate loading engine, the loading crew consists of a head loader, second loader, engineer, and fireman. Of course, if oil is used as fuel in the loading engine, the services of a fireman are generally dispensed with.

The following list is intended to approximate the average wages paid to members of the loading crew during the past six years. The wages designated "High" and "Low" do not represent extremes, but an average of high and low wages.

Wages of loading crew.

Position.	Average.	High.	Low.
Head loader	$4.25	$4.75	$3.50
Second loader	3.50	3.75	3.25
Gipsy, or loading-drum, tender	3.25	3.50	2.75
Loading engineer	3.25	3.50	3.00
Loading fireman	2.50	2.75	2.25

While this list of wages is substantially correct, taking it straight through the industry, it is to some extent misleading. Head loaders, where the output is large, are not infrequently paid $5 or more per day during what might be called normal times. Then, the engineer, or lever man, used in connection with the guy-line loading method, is sometimes paid as high as $5 per day. The success of this loading method depends largely on the skill of the lever man, and the number of really skillful lever men of this class is limited.

The cost per thousand feet of operating labor depends to a great extent on the output. The method used and the wages paid also influence this cost. The total labor cost per day of a loading crew, however, is to a great extent fixed. A certain crew has to be employed regardless of the output, and it follows that the operating-labor cost per thousand feet will be high or low in large measure as the output is high or low. This is illustrated in Table 24 and accompanying discussion.

TABLE 24.—*Operating labor cost per thousand feet for loading.*

Case.	Time.	Year.	Cost per thousand feet.	Location.
1	1 year	1912	$0.217	Columbia River district, Oregon.
2	do	1912	.112	Columbia River district, Washington.
		1911	.152	
3	do	1912	.247	Do.

Case 1.—The method of loading is shown in Figure 61. The output per day averaged about 67,000 feet The timber was small, the logs averaging about 600 feet in volume. The crew and daily wages were as follows: Engineer, $3.50; fireman, $2.50; head loader, $5; second loader, $3.75.

Case 2.—The method of loading is shown in Figure 61. The output per day averaged about 71,000 feet. The timber was large, the logs averaging about 1,900 feet in volume. At times the logs contained six, seven, or eight thousand feet, necessitating the use of slings instead of hooks, also the transference of the tail hold from the gin pole to the load. The crew and daily wages in 1912 were as follows: engineer, $3.25; fireman, $2.75; head loader, $3.75; second loader, $3.25 to $3.50. During part of this year oil was used as fuel, making a fireman unnecessary. Then at times it was not necessary to employ a second loader, the regular chaser of the yarding crew doing the work which is ordinarily done by a second loader. The output in 1911 averaged about 75,000 feet per day.

Case 3.—The method of loading was the same as that used in the previous case. The average output per loading day was about 57,000 feet, the logs averaging about 600 feet in volume. The crew and daily wages were as follows: head loader, $4; second loader, $3.50; engineer, $3.25; fireman, $2.75.

LANDINGS.

As a general thing the cost of landings per thousand feet is not classified in cost statements of logging operators, being included in the cost of either yarding or loading. Sometimes, of course, the cost of yarding and loading is segregated under one heading, the cost of landings being included in the cost of this combined step. Many operators, however, keep a landing account.

Landings are necessary with ground yarding and with some systems of loading. In the past landings were more of a factor in loading than now, which resulted in landings being associated with loading rather than yarding, and this association still continues.

In collecting and analyzing data dealing with the cost of landings care has to be exercised to determine what is included in the cost. It may include only the labor cost, or it may include the labor, material, and supply costs, also a rental on the equipment used in their construction. In addition to the cost of the landings proper, it may include the cost of raising gin poles, swinging rigging on gin poles, a part or all of the extended water system, and digging engine settings. These costs are handled differently by different companies.

The cost of landings per thousand feet of output varies with the type of landing, the character of the country, the number of landings per section, and the average stand per acre. The landings used with ground yarding are more elaborate than those used with high-lead or overhead yarding, especially in steep country, where considerable cribwork has to be done. The labor cost probably ranges between $50 and $300; in most cases from $75 to $150. The cost of landings in specific cases is given in Table 25 and accompanying discussions:

TABLE 25.—*Comparative costs of landings in specific cases.*

Case.	Number of landings.	Region.	Year.	Type.	Average cost.[1]
1	29	Columbia River	1912	Fig. 64	$155.00
2	100	Columbia River	1913	Fig. 64	135.00
3	75	West foothills, Cascades	1912	Fig. 72	100.00
4	8	Columbia River	1912	Fig. 64	208.00
5	8	Columbia River	1912	Fig. 64	130.00
6	30	Flat, west Cascades	1912	Fig. 72	$50.00–70.00
7	14	West slope, Cascades	1912	Fig. 72	95.00–175.00
8	15	Columbia River	1912	Fig. 72	285.00–340.00

[1] In no case does the cost include the timber used in the landings.

Case 1.—The cost includes the labor used in clearing sites, building landings, raising gin poles, swinging loading rigging, digging engine settings (yarding and loading), etc., in fact, everything except the moving of the yarding and loading engines. The country was practically level.

Case 2.—The cost is based on the landings constructed at three camps, representing a great variety of conditions, and includes the same items of expense as in the previous case.

Case 3.—The cost includes the labor and supplies used in building the landings and raising gin poles, the landings for the most part being constructed on relatively level ground.

Case 4.—The cost includes the same items of expense as in the first case, the landings being constructed in a mountainous country with a great variety of conditions.

Case 5.—Same as previous case.

Case 6.—The cost includes the labor used in constructing landings on practically level ground.

Case 7.—The cost includes the same items of expense as in the previous case, the landings being constructed on sidehill country. Six were constructed on the lower sides of the track at an average labor cost of $175; eight on the upper side, at an average labor cost of $95. Those on the lower side of the track contained 7,500 feet of timber on the average; those on the upper, 3,500 feet.

Case 8.—The cost includes the labor used in building the landings, for the most part on sidehill country. The following shows the crew and wages paid per day:

Hook tender	$4.50
2 rigging slingers	6.50
1 rigging slinger	3.00
Engineer	3.25
Fireman	2.75
Total per day	20.00

The number of landings depends on the character of the country. They are located along the spur railroads, and as the mileage of spur railroads per section increases the number of landings per section increases. Putting it another way, the number of landings increases as the maximum transportation distance from the stump to the landings decreases. More landings are necessary where all the timber is yarded direct to the track than where a part of it is swung or roaded, especially where a large part of the timber finds its way to the landings over pole roads. The distance between landings on the same side of the track depends on the chance and what the management thinks is proper. At one camp, where the ground was practically level, the landings on one side of the spur tracks were about 850 feet apart; at another, where conditions were practically the same, they were not more than 700 feet apart. It would seem that they should never be farther apart than 1,300 feet. One company operating in relatively level country is building about 50 landings per section; another, working in much the same character of country 24 per section; still another, working in mountainous country, where the logs have to be transported long distances by logging engines, 6 per section.

The cost of landings per thousand feet is greater in light stands of timber than in heavy stands. While fewer landings are built under the former conditions than under the latter, the reduction in the total cost because of this is not sufficient to offset the effect of the average stand per acre. Table 26 and accompanying discussion give the cost of landings per thousand feet at four camps.

TABLE 26.—*Comparative cost of landings per thousand feet.*

Case.	Time based on—	Year.	Cost per thousand feet.	Location.
1	1 year	1912	$0.09	Along the Columbia River, Oreg.
2	1 year 1 year	1913 1912	.09 .03	Do.
3	1 year	1912	.085	Do.
4	1 year	1912	.08	Flat west of Cascades.

Case 1.—The cost includes the labor used in clearing sites, building landings, raising gin poles, swinging loading rigging on gin poles, digging engine settings, etc., in fact, everything except the moving of yarding and loading engines. Landings of the type shown in figure 61 were used. The country was practically level.

Case 2.—The cost includes the same items of expense as in the previous case. In 1913, because of the character of the country, a larger number of landings were constructed, which is largely reponsible for a higher cost than in 1912. The country logged in 1912 was very mountainous.

Case 3.—The cost includes the same items of expense as in the first case. Landings of the type shown in figure 64 were used. Some of the timber was double hauled.

Case 4.—The cost includes the labor used in constructing landings of the type shown in figure 60. All the timber was single hauled.

As a rule landings are constructed by the same crew that clears the right of way for the spur railroads. Table 27, which shows the cost of three landings, indicates the division of labor, also the character of work. It will also serve to indicate how the cost of landings can vary because of what is included.

TABLE 27.—*Detailed cost of landings.*

Class of labor.	Case 1.			Case 2.			Case 3.		
	Number of hours.	Rate per hour.	Total cost.	Number of hours.	Rate per hour.	Total cost.	Number of hours.	Rate per hour.	Total cost.
Hooktender	78	$0.425	$33.15	20	$0.475	$9.50	37	$0.425	$15.72
Rigging men	108	.32	34.56	40	.325	13.00	56	.32	17.92
Signalman	78	.25	7.50	20	.25	5.00	37	.25	9.25
Engineer	58	.40	23.20	20	.40	8.00	37	.325	12.02
Fireman	78	.30	23.40	20	.30	6.00	37	.30	11.00
Wood buck	78	.25	19.50	20	.25	5.00	37	.25	9.25
Common labor	290	.25	72.50	100	.25	25.00	27	.275	7.42
Labor: Swamping, digging engine settings, and building landings			213.81			71.50			82.58
Labor; water system			25.80			24.00			
Total labor			239.61			95.50			82.58
Powder			8.25			5.00			4.50
Rental on engines			117.00			30.00			55.50
Total cost			364.86			130.50			142.58

Case 1.—The cost includes the clearing of site, yarding of the material, excavating for brow skids, etc., preparing and raising gin poles, swinging loading rigging on poles, digging settings for yarding and loading engines, as well as building the landing proper. The common labor in this case, as well as in the other two, did the pick-and-shovel work and such swamping as could be done by hand.

Case 2.—The cost includes the same items of expense as the previous case, except that it does not include the cost of preparing and raising the gin pole and the swinging of the loading rigging.

Case 3.—With the exception of the water system, this case includes the same items of expense as Case 2.

Generally speaking, the same equipment is used in building landings as in yarding, viz., a steam yarding engine, lines, blocks, chokers, etc.

One company has used a gasoline logging engine successfully for two years in building landings. It resembles the steam logging engine in a general way, and is a 40-horsepower two-cylinder, opposed type of engine. The combination of gears, drum, and frictions yields a high tractive efficiency, and gives, it is claimed, an engine that is capable of withstanding hard service. The drums and gears are erected on a built-up steel frame. The engine and 200-gallon water tank are independent of the drum mechanism, and are bolted securely to the sled. The power is transmitted by a No. 78 Griplock steel chain drive about 8 feet long, running from a 12-inch sprocket on the engine to an 18-inch sprocket on the countershaft, the latter being fitted with a 9-inch pinion. The engine has three drums, the frictions being such as to require very little pressure to hold the heaviest strain. It weighs about 7 tons, and is mounted on a sled 32 feet long and 4½ feet wide. A compressed-air tank, charged from the cylinders, furnishes about 50 pounds pressure for the operation of the signal whistle. The main drum carries 1,500 feet of ¾-inch line; the trip drum, 3,000 feet of ½-inch line; the loading drum, 300 feet of ⅝-inch line. The main yarding line can be made to travel 500 feet per minute; the trip line, 800 feet per minute. The cost of fuel has been approximated at $2.70 per 10-hour day, consisting of from 12 to 15 gallons of gasoline at a cost of 17 or 18 cents per gallon delivered at the engine. From 10 to 15 gallons of water are consumed per day.

This type of engine is also used at one camp for yarding timber suitable for piling and boom sticks from areas that have been logged once. Yarding is successfully done at a distance of from 1,000 to 1,500 feet. Three boom sticks, with 22-inch tops and 80 feet in length, can readily be handled at a trip. It is especially adapted for clearing rights of way and stump land, also pile-driver work. It was primarily designed for clearing stump land, for which purpose about 50 are in use. Engines of a smaller horsepower can be secured.

WIRE ROPE.

The cost of wire rope per thousand feet of loading output is dealt with in a general way under "Ground yarding." Ordinarily, the amount is small. With the single gin-pole loading method, the cost of the main loading and spotting lines per thousand feet is about $0.01. In the case of an overhead loading method, where no standing line is used, the cost of the main and trip loading lines and the spotting line per thousand feet is about $0.03. Where a standing line loading method is used, the cost of the loading and spotting lines per thousand feet ranges from $0.03 to $0.06, depending on the distance between the spar trees.

BLOCKS, HOOKS, TONGS, CARRIAGES, AND OTHER MISCELLANEOUS LOADING EQUIPMENT.

The maintenance and replacement cost of blocks, hooks, tongs, carriages, and other miscellaneous equipment per thousand feet depends on the loading method used. It ranges from $0.01 to $0.03.

FUEL.

The cost of fuel for logging engines is discussed in a general way under "Ground yarding." A loading engine burns between six and seven hundred feet of wood, or about four barrels of fuel oil per day.

LUBRICANTS.

The cost of lubricants used in loading is about $0.006 per thousand feet of output.

MAINTENANCE.

The maintenance of a loading engine costs about $150 per year, this amount being about equally divided between labor and new parts, material, etc.

DEPRECIATION.

The Forest Service in connection with timber-appraisal work has placed the life of loading engines at eight years, and has assumed that the engines at the end of that time will be worth about 10 per cent of the initial cost. The depreciation on a loading engine that cost $2,700, together with the fuel-oil-burner equipment, water and oil tank, sled, etc., amounts to about $425 per year, or about $0.035 per thousand feet.

RAILROAD TRANSPORTATION.

The bulk of the timber logged in the region is conveyed over standard-gauge railroads to the mills or large bodies of water for distances ranging from a mile or two to 30 miles or more. The entire length of line may be owned by the logging operator, or the logging road only be used to deliver the logs to some point on a common-carrier railroad.

Bryant, in "Logging," states that the successful use of steel-rail logging roads began in 1876. The number of logging railroads increased rapidly, and by 1881 there were 71 in operation in Michigan and 5 in Wisconsin. The first on the Pacific coast was operated about 1885. Railroad transportation was used on the coast practically as soon as the length of haul made it the most economical method, so that it did not have to supplant other methods, except in a few cases. Now it is the preferred form of transportation, the Grays Harbor and Willapa Harbor districts being the only ones where it is not exclusively used.

Railroads have made accessible large bodies of timber which otherwise could not be logged, since the conditions in the region, for the most part, are not favorable for driving. This mode of transportation has several other advantages over other forms. The logging operator does not have to wait for flood waters to float the logs to the mill or market, to anticipate market conditions in advance, to have large sums of money tied up along the banks of streams, or to lose logs in transit. Furthermore, the railroad delivers clean logs to the mill, which results in an appreciable saving in cost of manufacture.

COMMON-CARRIER RAILROADS.

While some of the long hauls are made over railroads owned entirely by the logging companies or closely affiliated companies, most of them are made over common-carrier railroads.

RATES.

In Table 28 is given a list of specially quoted log rates charged by common-carrier railroads in Oregon and Washington in 1913.

TABLE 28.—*Freight tariffs on logs in 1913.*

Name of railroad.	Hauling distance.			Established rates on logs per 1,000 feet between points involving a haul of—							Remarks.
	Miles.	Shipping point.	Delivery point.	Less than 20 miles.	20-30 miles.	30-40 miles.	40-50 miles.	50-60 miles.	60-70 miles.	70-80 miles.	
Northern Pacific Railway Co.	4	Crescent, Wash.	Sumas, Wash.	$0.60							Minimum charge, $6 per car.
Do.	22	Acme, Wash.	Bellingham, Wash.		$1.40						Minimum, 7,000 per car.
Do.	67	Wickersham, Wash.	Everett, Wash.						$1.85		Do.
Do.	48	Hazel, Wash.	do.				$1.25				20 or more cars; 7,000 per car, minimum.
Do.	41	Oso, Wash.	do.				1.60				
Do.	72	do.	Fremont, Wash.							$1.90	
Do.	45	Fortson, Wash.	Everett, Wash.				1.60				
Do.	15	Bordeaux, Wash.	Olympia, Wash.	.90							15 or more cars; 7,000 per car, minimum.
Do.	28	Porter, Wash.	Aberdeen, Wash.		1.25						Do.
Do.	22	Elma, Wash.	do.		1.00						10 or more cars; 7,000 per car, minimum.
Do.	17	Satsop, Wash.	do.	1.25							Do.
Do.	13	Tulips, Wash.	Hoquiam, Wash.	1.25							
Do.	30	Lytle, Wash.	do.			$1.25					Do.
Do.	30	Porter, Wash.	do.			1.25					Do.
Do.	18	Francis, Wash.	Raymond, Wash.	1.35							
Do.	35	Pilchuck, Wash.	Everett, Wash.			1.55					
Do.	45	Yacolt, Wash.	Felida, Wash.				1.00				15 or more cars; 6,000 per car, minimum.
Do.	38	Easton, Wash.	Ellensburg, Wash.			1.55					
Do.	49	Stampede, Wash.	do.				1.65				
Do.	20	Wickersham, Wash.	Bellingham, Wash.		1.40						
Do.	17	Globe, Wash.	Raymond, Wash.	1.35							
Do.	32	Robe, Wash.	Everett, Wash.			1.50					
Do.	14	Wingate, Wash.	Puyallup, Wash.	1.25							
Do.	18	Orting, Wash.	Tacoma, Wash.	1.00							10 or more cars; 7,000 per car, minimum.
Do.	10	Weatherwax, Wash.	Aberdeen, Wash.	.60							Minimum; 7,000 per car.
Do.	14	do.	Hoquiam, Wash.	1.00							Do.
Do.	29	Spiketon, Wash.	Tacoma, Wash.		1.10						Single cars, $1.25 per 1,000; 10 or more cars, $1.10.
Do.	63	Bunker, Wash.	Aberdeen, Wash.						1.65		

Chicago, Milwaukee & Puget Sound Railway Co.	25	Duvall, Wash	Everett, Wash		1.00						Less than 10 cars, $1.25 per 1,000.
Do	25	Maple Valley, Wash	Seattle, Wash		1.40						Minimum, 7,000 per car.
Do	19	S. Elma, Wash	S. Aberdeen, Wash	1.10							10 or more cars, $1.10 per 1,000; single cars, $1.40, minimum, 7,000.
(Tacoma & Eastern)	25	Tidewater, Wash	Tacoma, Wash		1.00						Single cars, minimum, 5,000 per car.
Do	10	Ashford, Wash	Mineral, Wash	.60							Minimum, 6,000 per car.
Do	65	Lindberg, Wash	Tacoma, Wash						1.40		Single cars, minimum, 6,000 per car.
Do	45	Reliance, Wash	do				1.20				Do.
Do	19	Morton, Wash	Elbe, Wash	.80							Do.
Do	45	Lindberg, Wash	Kapowsin, Wash				1.20				Do.
Southern Pacific Railway Co. (Pacific R. R. & Navigation Branch).	13	Rector, Oreg	Wheeler, Oreg	1.10							
Do	59	Timber, Oreg	Newberg, Oreg					$2.25			Minimum, 6,000 per car, 1 car or more.
Southern Pacific Railway Co.	18	Marcola, Oreg	Eugene, Oreg	1.75							
Southern Pacific Railway Co. Salem (Falls City & Western Branch).	20	Falls City, Oreg	West Salem, Oreg		1.50						
Do	14	Black Rock, Oreg	Dallas, Oreg	1.00							
Do	10	Greenburg, Oreg	Falls City, Oreg	1.00							
Great Northern Railway Co.	13	Sultan Crossing, Wash.	Snohomish, Wash	.90							Minium, 6,000 per car.

At the time the above rates were in effect, the Northern Pacific Railroad Co. quoted distance rates as follows, the special rates mentioned above to be applied when less than the distance rates. These distance rates deal with all main and branch line stations in the State of Washington west of and including Ellensburg, Wash., except the haul between Granite Falls and Robe, Wash., on the Monte Cristo Branch.

TABLE 29.—*Distance, freight tariffs.*

[Minimum, 7,000 feet per car.]

Distance.	Rate in dollars per 1,000 feet.
10 miles or less	$1.00
Over 10 miles and not over 15 miles	1.25
Over 15 miles and not over 20 miles	1.35
Over 20 miles and not over 25 miles	1.40
Over 25 miles and not over 30 miles	1.45
Over 30 miles and not over 35 miles	1.50
Over 35 miles and not over 40 miles	1.55
Over 40 miles and not over 45 miles	1.60
Over 45 miles and not over 50 miles	1.65
Over 50 miles and not over 55 miles	1.70
Over 55 miles and not over 60 miles	1.75
Over 60 miles and not over 65 miles	1.80
Over 65 miles and not over 70 miles	1.85
Over 70 miles and not over 75 miles	1.90
Over 75 miles and not over 80 miles	1.95
Over 80 miles and not over 85 miles	2.00
Over 85 miles and not over 90 miles	2.05
Over 90 miles and not over 95 miles	2.10
Over 95 miles and not over 100 miles	2.10
Over 100 miles and not over 110 miles	2.15
Over 110 miles and not over 120 miles	2.20
Over 120 miles and not over 130 miles	2.25
Over 130 miles and not over 140 miles	2.30
Over 140 miles and not over 150 miles	2.35

It should be noted in connection with the special rates that the rates depend on the amount shipped; also that the rates are applied in connection with a carload minimum. In a specific case it is easy to measure the effect of the former, while the latter is difficult to get at. If the logs are large and sound, the latter will have the effect of increasing the quoted rate but little, if any. Where the logs are small and extreme care is not used in loading, the actual rate per thousand feet may be 10 or 15 per cent higher than the quoted rate. One company, operating in small second-growth timber and paying a quoted rate of $1 per thousand feet, found at the end of a year that they had actually paid $1.15 per thousand feet, the increase being due to the fact that a large number of the cars did not contain the minimum carload established by the railway company. The next year this company, through more careful loading, kept the actual rate equal to the quoted rate, This was not easy, however. The logging superintendent found that the loaders did not see or appreciate the effect of underloads on the actual rate and in turn on the cost of logging. The mere telling the loaders to be sure to put the minimum carload on a car did not remedy the evil, neither did discharging the loaders. It was only when the superintendent, with the scaler, worked with the loaders, pointing out the underloads on the ground and demonstrating by mathematics the increased cost of transportation per thousand feet because of specific underloads, that the evil of the underload wss gotten away from.

As a rule, logging operators pay for log transportation on the basis of the railroad company's scale. This scale in most cases approaches a gross scale, while the logging operator sells his logs and estimates his logging cost on the basis of a net scale. Where the logs are sound, the difference between the quoted and actual rate is small. In some cases, however, the difference amounts to considerable. One operator, shipping on a quoted rate of $1.25 per thousand feet, found that the cost actually amounted to $1.55; another company, shipping on a quoted rate of $1.50 per thousand feet, actually paid $1.85 per thousand feet.

LOGGING RAILROADS.

LOCATION.

The locating of the main-line railroad and primary spurs is the most important step in the logging operation. Failure to open up a tract of timber at the right point may spell failure. Mistakes in connection with other steps can be corrected. It is not so in the case of the railroad location.

In general the location and character of a logging railroad depend on the amount of timber it is to handle and the time it is to be operated. The longer any railroad is to be used and the heavier the traffic, the better it should be constructed. In any case, the cost of construction should be the smallest amount consistent with reasonable operating and maintenance costs. Logging railroads are invariably constructed more cheaply than even branch trunk lines, a shorter operating period making heavier grades, sharper curves, and a poor roadbed practical. The amount of traffic that is to pass over the main line and each of the spurs, the total rise and fall which must be overcome (as indicated by a topographic map or a careful reconnaissance), and the speed with which the timber is to be removed are guiding factors in deciding on the character of roadbed that should be built and the kind and amount of motive power that should be used.

Topography largely fixes the locations, but the general plan of logging determines whether the railroad lines, especially the spurs, shall follow valleys, ridge faces, or the tops of ridges. Spurs are generally constructed wherever necessary to bring the timber within economic yarding, swinging, or roading distance of the track.

In most cases the main line enters the tract at the lowest point, following water grade wherever possible, since this location usually gives the best grade out of the region and permits the logs to be hauled down grade. Obviously, this is not possible in all cases, especially where the topography of the country is such that the spur railroads are laid on ridges and the timber yarded up grade. The shortest possible route, naturally, is selected, unless heavy cuts, fills, bridge work, and trestle work can be avoided by a longer line. Switchbacks are frequently used to overcome sharp changes in the grade. The same end may be gained more satisfactorily by doubling back with a curve. This latter method, however, often necessitates a heavier construction expense. Switchbacks often are the only practical means at hand for securing timber from elevations above or below the main line. When the rise in elevation is considerable, it may be advisable to put in an incline.

Under "Ground yarding," it was pointed out that where the ground is practically level the spur railroads are located so as to gridiron the tract, the distance between the spurs depending for the most part on the cost of the roadbed and the stand of timber per acre. Figures 16 and 17 show how the spur roads may be located in practice. In the first case the conditions from the standpoint of railroad construction approach the ideal. In the second case the ground conditions were harder than usual, which resulted in the timber being yarded and swung relatively long distances to the railroad. Spur railroads are located by the foreman or superintendent or by a logging engineer.

Grades and curvature.—The maximum grades and curvature allowed on any logging railroad vary with the character of the road and the type of locomotives used. Heavier loads must be hauled on the main lines than on the spurs, hence the grades and curvature must be lighter. If a geared locomotive is used, they may be heavier in either case since a geared locomotive can negotiate heavier grades and sharper curves than a rod engine.

The direction of the traffic and whether or not there are adverse grades must be considered in a discussion of grades and curvature. Traffic on logging railroads moves only one way, the general direction, as a rule, being down grade. Not infrequently, however, adverse grades are found on these roads, and they limit the number of cars that can be hauled at a trip. The effect of grade on the number of cars, unloaded and loaded, that can be hauled at a trip is illustrated in Table 30.

TABLE 30.[1]—*Effect of grade on number of cars that can be hauled at a trip.*

TRAFFIC DOWN HILL.

Rate of grade (per cent).	Resistance in pounds per ton.	Weight of locomotive (tons).	Number of empty cars per train (uphill).	Capacity of train in feet board measure of logs (downhill).	Capacity of each car in feet board measure of logs.	Weight of empty cars (tons).
1	30	60	62	310,000	5,000	10
2	50	60	36	180,000	5,000	10
3	70	60	25	125,000	5,000	10
4	90	60	19	95,000	5,000	10
5	110	60	15	75,000	5,000	10

TRAFFIC UPHILL.

Rate of grade (per cent).	Resistance in pounds per ton.	Weight of locomotive (tons).	Number of loaded cars per train (uphill).	Capacity of train in feet board measure of logs (uphill).	Capacity of each car in feet board measure of logs.	Weight of loaded cars (tons).
1	26	60	19	95,000	5,000	27
2	46	60	14	70,000	5,000	27
3	66	60	9	45,000	5,000	27
4	86	60	7	35,000	5,000	27
5	106	60	5	25,000	5,000	27

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[1] From The Timberman.

Except when topographic conditions forbid, long main-line logging railroads are usually constructed to permit the use of rod engines. When such engines are used, the grades should not exceed 3 or 4 per cent where empty cars are moved up grade and 1 per cent in the case of loaded cars; and the sharpest curves should not exceed 16 degrees. In the more mountainous region, the main lines can not be constructed for the use of rod engines except at a prohibitive cost, so that geared engines must be used. In such cases, the maximum grades do not ordinarily exceed 5 per cent when empty cars are to be hauled up them and 2 per cent in the case of loaded cars. The maximum curves used with a geared locomotive, as a rule, do not exceed 20 degrees.

Logging spurs are usually constructed for the use of geared engines, since the grades and curves on these lines must be heavier than those required on the main lines. Ordinarily, the maximum grade for empty cars is 7 or 8 per cent; for loaded cars, 3 or 4 per cent. Most operators try to keep the maximum curvature of the spurs down to 20 degrees, although in extreme cases the curvature may run as high as 50 degrees.

Methods of location.—The engineering steps preceding the building of logging railroads, while not always so clearly defined or performed in the same way, are in general the same as those preceding the construction of a common carrier railroad. They are (*a*) reconnaissance, (*b*) preliminary survey, and (*c*) location.

The reconnaissance in the case of main-line logging railroads consists of a more or less rapid examination of possible routes, with the following objects in view: To determine the most feasible and economical line between the timbered area and the delivery point; to locate the controlling points, which consist of stream crossings, summits of ridges, and other natural or artificial features of the territory through which the road must necessarily pass in order to make the largest amount of timber accessible; to determine the maximum grade and the maximum degree of curvature; to ascertain the kind of materials likely to be encountered in the construction of the road to determine the effect of the materials on the cost of maintenance; and to obtain a general idea of the approximate cost per mile of the completed road. This constitutes in the main the field work performed by a timber appraiser. From the information so secured, together with information usually secured by a preliminary survey, he must estimate the approximate cost of the main line.

For the purpose of determining relative elevations, maximum grades and curves, the directions of streams and roads, etc., the timber appraiser usually provides himself with an aneroid barometer, a pocket compass, and a hand level. With this equipment he personally investigates all important points involved and makes comprehensive notes of all topographic features along the route, such as the size and direction of streams, together with their high-water marks; the slope of important waterways that must be crossed; and any other information concerning them that can be secured. Such information as can be secured regarding the character of the soil and the prevalence of rock is carefully noted. In addition the appraiser notes the probable quantities of excavation, embankment, and bridging per mile; also any other data which will assist him in estimating the cost of the proposed railroad.

The method in the case of spur railroad is in large measure the same as that used for the main line, in that some one determines, after making an examination of the tract to be logged, the general routes of the main spurs.

Many operators in the region consider topographic maps an essential part of their equipment. These are prepared in connection with the timber cruise, or by engineers before the tract is opened up, the contour intervals ranging from 10 to 50 feet, depending on the accuracy required and the roughness of the country. Such a map furnishes a basis for the preliminary location.

The reconnaissance of the main line having been completed and a route selected, the next thing is to make a preliminary survey of the main line for the following purposes: To determine the relative merits of alternative routes that have been examined on the reconnaissance; to obtain the necessary information for making a map and a profile of the route; to furnish data from which to project the location; to determine the approximate amount of work to be done in the matter of clearing, grading, and bridging; and to furnish data for an approximate estimate of the cost of all materials and labor required for the proposed road.

While most of the large companies employ a logging engineer to lay out their logging spurs, some have this work performed by the camp foremen. In the former case the engineer, in cooperation with the superintendent or foreman, roughly determines the routes of the spurs. This cooperation insures the maintenance of the proper balance between the railroad and the logging. The preliminary survey is then made. The engineer is aided by one or two rodmen and two or more axmen, depending on the density of the brush. As a rule, the engineer uses a transit on preliminary work, because of the accuracy demanded in the final results. The foreman generally uses a compass and a hand level of the Abney type.

The line is fitted to the ground in such a manner as to secure the best adjustment of the alignment and grade consistent with an economical cost of construction. If no topographic map is available, the work of location is done directly on the ground. In many cases, however, a contour map is prepared from the data secured by the preliminary survey, on which the location is projected.

Logging engineers may be employed by the month or year, at a salary ranging from $100 to $150 per month. In either case they may devote much of their time to mapping. In some cases engineers are used only on particularly difficult locations, being paid by the day. Arrangements are sometimes made whereby an engineer divides his time between two or more camps. The cost of engineering ranges from $150 to $400 per mile.

RIGHTS OF WAY.

Not infrequently logging railroads have to be built across the land of others. Under such conditions the land may be bought at private sale or it may be leased for a period sufficient to permit the removal of the timber. The second is the more satisfactory method, since a narrow strip of land is of little value to the owner, and it is difficult to sell at the conclusion of a logging operation. Of course, if the road is ultimately to become a common carrier, the former would be desirable. Should a right of way be refused, a line can be forced across foreign holdings by condemnation proceedings and the payment of just compensation to the owner, the operator, however, forfeiting certain rights. For example, a logging operator acquiring a right of way by condemnation proceedings must agree to carry over such road any of the timber or other forest products of the lands through which such right of way passes, upon payment of a reasonable consideration, and failure to do so results in a forfeiture of the right of way.

CLEARING THE RIGHT OF WAY.

Before starting the grading of the right of way, it is necessary to cut and remove the standing timber, brush, and stumps which will interfere with the roadbed. This work is done by both contract and day labor. The right of way varies in width, seldom being wider than 50 feet. It is not possible to speak confidently of the cost of this work, since operators, as a rule, do not classify their accounts in such a way as to make it possible to secure data that are at all satisfactory. The average cost should not exceed $500 per mile, where the stumps are blasted and the timber is dragged from the road with a logging engine. The following piecemeal data will serve to indicate the method of performing this work, also what the total cost consists of.

(*a*) In one case the cost of bucking the down timber on a mile of right of way ahead of the fallers amounted to $55.

(*b*) The labor cost of felling the timber (13 trees) on 400 feet of right of way amounted to $3.75. One of the fallers was paid $4 per day, the other $3.50. The diameters of the trees were as follows:

Number of trees (hemlock):	Diameter in inches.
2	16
2	17
1	18
1	20
2	24
1	28
2	30
1	32
1	60

(*c*) The cost of blowing 24 stumps on 600 feet of right of way amounted to $40, as follows:

5 boxes of powder, at $0.11 per pound	$27.50
1 man, at $3.50 per day	3.50
4 men, at $2.25 per day	9.00
Total	40.00

The diameters of the stumps were as follows:

Number of stumps (hemlock):	Diameter in inches.
7	16
2	17
4	24
2	32
2	42
4	48
3	60

(*d*) The cost of blowing 8 stumps on 200 feet of right of way amounted to $31.25, as follows:

5 boxes of powder, at $0.11 per pound	$27. 50
40 caps	. 55
50 feet of fuse	. 20
Labor	3. 25
Total	31. 50

This is at the rate of $836 per mile. If, however, there were fills, all the stumps would not have to be blown out. The diameters of the stumps were as follows:

Number of stumps (hemlock):	Diameter in inches.
2	16
1	17
1	24
1	32
1	42
1	48
1	60

(*e*) The labor cost of swamping and blowing the stumps from 500 feet of right of way amounted to $75.48. The cost of felling is not included in this, neither is the cost of moving the logging engine or extending the water system. Common labor dug the holes under the stumps and the chunking crew loaded and shot them. The size and wages of the chunking crew were as follows:

	Per day.
Hook tender	$4. 50
Engineer	3. 50
Fireman	3. 00
Wood buck	2. 75
4 rigging men, at $3.25	13. 00
Total	26. 75

The common labor was paid $2.75 per day.

(*f*) The labor cost of clearing 13,350 feet of right of way was $2,454. This is at the rate of $977 per mile. The stand of timber through which the right of way ran was cutting out about 50,000 feet per acre, consisting of Douglas fir and hemlock. It averaged about 32 inches in diameter, breast high. The chance from the standpoint of down timber, brush, and dead snags was unusually difficult. There were no heavy fills.

GRADING THE RIGHT OF WAY.

Fills and cuts are introduced to equalize the irregularities of the soil, the process being known as grading.

Fills on standard gauge logging roads should be from 12 to 14 feet wide on top. The standard slopes for an earthwork fill are $1\frac{1}{2}$ horizontal to 1 vertical. When the fill is made of the material from a rock cut, it is possible to make a stable embankment with a slope ratio of 1:1. On sidehill work, where a slope of $1\frac{1}{2}$:1 or 1:1 might be a very long slope, it is often advisable to make a wall of rock or timber that will have a slope ratio of $\frac{3}{4}$:1 or steeper.

In cuts the roadbed should be wide enough to give room for a drainage ditch on either side. This will require from 2 to 3 additional feet on each side, and the cut should be about 16 feet at the base. With cuts in the hardest rock the slopes will be $\frac{1}{4}$:1, or nearly perpendicular. As the soil becomes less firm the slope may be flattened until, for a soil of firm earth or gravel, a slope of 1:1 may be permissible, although a slope of $1\frac{1}{2}$:1 is commonly adopted. The aim is to move as little dirt as possible.

Main-line logging roads are graded up carefully, and suitable ditches are maintained. Even on level sections it is desirable to elevate the track and put in ditches because of the lower cost of maintenance during wet weather. On spurs a minimum of fill and cutwork is done, and ditching is not resorted to unless absolutely necessary.

For the purpose of constructing a road as well as for calculating the earthwork, a grade profile or profiles may be prepared. This enables the engineer to fit the line to the ground in such a manner as to secure the best adjustment of the alignment and grade consistent with an economical cost of construction. It is not practical or necessary, however, for a timber appraiser to secure such intensive data, and his estimate of the cost of grading in a given case is not more than substantially correct. The appraiser's estimate, however, should be high enough to cover all cost, a liberal allowance being made to cover unforeseen contingencies that may develop during construction. Handbooks prepared for the use of civil engineers deal with the methods of calculating the cubical contents of earthwork.

The cost of the movement of earth depends to a great extent on the character of the material. The following extract from "Logging," by Bryant, shows the effect of the character of the material moved on the cost of grading:

> The movement of earth and rock in the construction of cuts and fills is most frequently done by contract. The unit on which payment is based is the cubic

yard, the material being measured "in place"—that is, in the natural bank before it has been disturbed. It is customary to classify the material to be moved, and to regulate the price accordingly. The classification and quantity of material moved are determined by the supervising engineer.

The following standard classification is in extensive use:

(*a*) Earth, loam, sand, gravel, or clay. Material that can be handled with a pick and shovel, or that can be plowed easily.

(*b*) Hardpan. Very dense clays and gravels, cemented with iron oxide. Soft shales that are easily worked may also be included.

(*c*) Loose rock. Shales and other rock that can be quarried without blasting, although blasting may be resorted to occasionally.

(*d*) Solid rock. Material requiring blasting for removal.

The contract price per cubic yard for the removal of earth or rock usually includes excavating, hauling, and placing the material in a fill or waste pit. It is not customary to pay for making a cut and also to pay for a fill made from the same material; in other words, payment for a cubic yard is made but once. Grading contracts may have an overhaul clause which provides that for all earth hauled more than a specified distance ("free haul") the contractor shall be paid a stated sum per cubic yard for each 100 feet of overhaul. On logging operations the length of free haul ranges from 100 to 500 feet.

The price paid for moving material varies greatly in different regions and is influenced by the length of haul, the kind of material moved, the character of classification, the degree of accuracy used in actual classification, and the season of the year; the cost of winter work being about 25 per cent higher than that of work done during the summer.

The following prices were paid on logging railroad operations and represent general contract prices on work of this character. The average work on logging roads, except on the Pacific coast, usually presents no special problems, and can be performed with simple equipment which does not require a heavy financial outlay. Loggers are able, therefore, to contract with local men on favorable terms.

Material.	Alabama.			Louisiana.	Texas and Arkansas.	Washington.		
	Contract price.	Free haul.	Bonus for overhaul per 100 feet.	Contract price.[1]	Contract price.[1]	Contract price.[1]	Free haul.	Bonus for overhaul per 100 feet.
	Cents.	*Feet.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Feet.*	*Cents.*
Earth	25	300	0.5	14	20	16–20	100	0.5
Hardpan			.5			25	100	.5
Loose rock	35	300	.5			35–45	100	.5
Solid rock	65	300	.5			75–125	100	.5

[1] No limit to free haul, but it was not great in any case.

Much of the grading for logging railroads is done by hand; that is, by pick and shovel work. This is particularly true of sidehill work where the bank may be picked away and shoveled to the lower side. Light work on fairly level ground is done in the same way, the dirt being borrowed from ditches or borrow pits. Frequently, moderate-sized cuts and fills, under favorable soil conditions, are handled in the same way, the material from the cuts being mostly wasted and that needed for the fills borrowed.

Pick and shovel work is usually done by day labor, as are all other parts of railroad construction, contract work not being regarded favorably by most operators in the region. The cost of digging and spreading dirt by pick and shovel is commonly about $0.15 to $0.25 per yard for common loam and $0.30 to $0.35 for heavy soils.

In large cuts the dirt is moved to adjacent fills with wheelbarrows, two-wheeled hand dump carts, or push cars. The cost of such work, where rock is not encountered, ranges from $0.30 to $0.50 per yard. In very large cuts it is sometimes the practice to lay a temporary track and remove the dirt by shoveling it by hand on flat cars, the cars being hauled out on the line to a point where the dirt can be used as ballast.

Many operators supplement the pick and shovel with power scraper work. The labor cost of this work ranges from $0.10 to $0.25 per yard, depending on the length of haul and the class of material moved. The cost of moving dirt at one camp with a power scraper during one season ranged from $0.28 to $0.38 per yard. The equipment consisted of a logging engine, Bagley scraper, lines, etc., the crew and the wages per day being approximately as follows:

Engineer	$3.40
Fireman	3.00
2 wood bucks, each	2.75
Hook tender	4.25
1 or 2 riggers, each	3.25

The following record shows what is included in the cost of power scraper grading at this camp, also the method of keeping track of the cost:

Power scraper record.

Time.	Items of cost.	Total cost.	Cost per yard.
Hours.			
60	Moving machinery to place	$37.50	$0.0095
	Chunking right of way	262.50	.0668
85	Laying water line	40.50	.0103
235	Rent on machinery, at $1.50	352.50	.0897
235	Engineer, at $0.315; fireman, at $0.275; wood buck, at $0.25	206.39	.0525
235	Hook tender, at $0.50	117.50	.0296
	Rigging men	153.43	.0390
	Laborers (finishing work)	69.33	.0176
	Yarding wood logs	16.55	.0042
	Total cost moving 3,927 yards	1,256.20	.3192

Average amount of dirt moved per hour of actual scraping time, 16.7 yards.

Ground, average conditions.

Alignment, 40° curve.

Remarks: Because of the alignment this cut was scraped from each end.

The equipment used with a power scraper consists of a logging engine, lines, blocks, etc. The cost and maintenance of the equipment, also the depreciation that should be written off annually, are discussed under "Ground yarding." In a general way this work is harder on equipment than ordinary yarding, since the percentage of time that the equipment is actually in use is larger. Several scrapers are used, the size and cost in March, 1916, of one of the best being as follows:

Size.	Cost.
4 yards	$400
5 yards	450
6 yards	500

Comparatively few of the operators use a steam shovel. A 1½-yard dipper steam shovel suitable for heavy work costs about $8,000 at Portland or Seattle. A smaller one with a ⅞-yard shovel costs about $5,600 at these points.

It has not been deemed advisable or practicable to enter into a lengthy discussion of the methods and cost of grading. Information of this kind is difficult to secure. It is easy to find out the amount of money expended by a logging operator for labor in railroad construction, but it is usually impossible to get it classified into the cost of clearing right of way, grading, etc., in connection with the total length of line built, the total amount of earth moved, a classification of material moved, etc.

The cost of grading, obviously, varies greatly. In places, for short stretches, it can be done for as little as $10 per station (100 feet). In other places it costs $20, $30, $40, $60, or more per station. Taking it straight through the country the cost of grading the spur railroads probably ranges between $30 and $50 per station. For example, the cost of grading 13,350 feet in one case, with pick and shovel, amounted to $6,664, which is at the rate of about $2,630 per mile. This does not include the cost of clearing the right of way, which was cleared for $997 per mile. It was a scratch grade for the most part, there being no heavy cuts or fills. The average cost of clearing right of way and grading 25 miles of track in another case during 1910, 1911, and 1912 was $2,300 per mile. The cost per station ranged between $28 and $64, the average being $44. These figures do not include the cost of trestle construction. During this time, seven miles of rather heavy sidehill grade was constructed. There was little rock, and no heavy cuts or fills. The work was done by contract, the operator paying $40 per station when the cuts and fills did not exceed 3 feet in depth. It was all done by the pick-and-shovel method. Another operator working in moderately rough ground has cleared and graded the right of way for spur tracks for a number of years at the rate of $1,500 per mile. Still another operator who constructs from 14 to 30 miles of spur track per year has found that the cost of clearing right of way and grading is from $27 to $30 per station. This work includes cuts to a depth of 10 feet, fills to a height of 7 feet, with many of the cuts and fills running more than 5 feet. The operator lets the contract to two men, and the net profit to each has never been less than $250 per mile.

TIMBERWORK.

Much printed matter dealing with the character and cost of cribbing, trestles, revetments, etc., and methods of construction is available. A simple treatment is given in "Logging," by R. C. Bryant. For this reason the discussion given here is only very general.

(1) *Cribwork.*—In the past cribwork was extensively used and is still used in places to cross slight depressions or swampy ground. It consists of large logs laid at right angles to the track about 12 feet apart, center to center. Two logs are laid lengthwise on these logs for stringers. The cost of cribbing, when the height runs from 4 to 5 feet, is from $0.50 to $0.75 per linear foot, exclusive of the stumpage. From 400,000 to 500,000 feet board measure of logs is required per mile.

Cribwork, however, frequently costs more than this, as is shown in the following cases:

Case 1.—The cost of a three-stringer crib bridge 83 feet in length and 5 feet high was $223.75, or $2.70 per linear foot, segregated as follows:

Excavating, labor	$12.50
Construction, labor	116.25
Rent of equipment	90.00
Finishing, labor	5.00
Total	223.75

Case 2.—The cost of a cribbing 100 feet in length and averaging 10 feet in height was $542.38, or $5.43 per linear foot, segregated as follows:

Excavating, labor	$66.75
Construction, labor	290.63
Rent of equipment	172.00
Finishing, labor	13.00
Total	542.38

This structure forms the tail of a switchback, with two bridges resting on one foundation, the alignment necessitating three stringers. There is one span 50 feet in length and two spans 25 feet in length.

Case 3.—One camp in 1913 used crib bridges exclusively, the cost ranging from $2 to $6 per linear foot, exclusive of the stumpage, and varying for the most part with the height. Cribbings 20 feet in height cost about $6 per linear foot.

(2) *Trestles.*—Trestles are used in crossing streams and depressions when the cost of fills would be excessive, also on swampy or moving ground where no other method would be practical. The advantage of this form of road on swampy ground is that a firm foundation is secured, stumps need not be removed, and the cost of maintenance for the first few years is low. The main disadvantage is the fire danger. This, however, can be minimized by clearing away the brush on each side.

Two types of trestle are used in the construction of logging railroads in the region; namely, pile-bent and frame-bent trestles.

(*a*) Pile-bent trestles are used largely in stream beds and swampy spots where good foundations for frame trestles can not be secured. They are used extensively, however, in locations adapted for the frame-bent type. Low pile trestle bents, up to a height of 25 feet, consist of 3 or 4 piles from 12 to 15 inches in diameter. On medium height trestles, from 25 to 60 feet, four piles are used. They are driven in a row across the roadbed with a pile driver to bedrock or solid bottom, being sawed off at the required height above ground. Hewn caps, 14 feet long, 12 inches and up in thickness, with not less than a 12-inch face, are drift-bolted on top of them. The bents, which are spaced 16 feet apart, are connected by two hewn or sawed stringers 16 or 32 feet in length and 17 inches and up in thickness, with 12 to 16 inch faces, a stringer being placed under each rail on top of the caps and at right angles to them to support the crossties. In many cases hewn stringers prove the cheapest in the long run.

Guard rails are placed on top of the ends of the ties parallel to the stringers and spiked to every other tie to keep the ties from bunching. Trestles over 25 feet in height, as a rule, are braced by standard methods. If a trestle curves heavily it is braced, even though it is no more than 15 feet high.

The labor cost of constructing pile-bent trestles of the above description is about as follows:

Average height:	Cost per linear foot.[1]
5 to 10 feet (no bracing)	$2.00
10 to 15 feet (no bracing)	2.20
15 to 20 feet (no bracing)	2.50
20 to 25 feet (with bracing)	3.00
25 to 40 feet (with bracing)	4.00
40 to 60 feet (with bracing)	5.00

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[1] Includes the cost of yarding the material to the site.

The following is the cost of several pile-bent trestles built in logging camps of the region during the past few years:

Case 1.—The labor cost of a pile-bent trestle 1,800 feet long and averaging 5 feet in height amounted to $900, or $0.50 per linear foot. The bents consisted of three piles; the caps and stringers were hewn hemlock timber.

Case 2.—The cost of building a three-pile-bent trestle 160 feet in length and averaging about 20 feet in height amounted to $464, or $2.90 per linear foot, the cost being made up as follows:

Excavating	$106
Labor, including surveying to the amount of $40.75	265
Rent of machinery	60
Finishing (including laying of steel)	33
Total	464

This amount includes the cost of yarding the material to the site. It does not include the cost of timber or iron used. The caps and stringers were made of hewn timbers.

Case 3.—The cost of building a pile-bent trestle 1,200 feet in length and averaging about 10 feet in height amounted to $5,428.31, or $4.52 per linear foot, the cost being made up as follows:

Stringers, caps, and iron	$1, 450. 81
490 piles (25 feet in length) at 7 cents per foot	857. 50
Towing piling	70. 00
Lumber, 14,000 feet, at $8 per thousand	112. 00
Labor	2, 938. 00
Total	5, 428. 31

Case 4.—The cost of a pile-bent trestle 135 feet in length and averaging about 28 feet in height was $5.20 per linear foot. This includes the cost of yarding the material to the site and building the trestle, also a rental of $5 per day on the equipment. It does not include the value of the timber, sawed or otherwise.

The bents consisted of four piles, the trestle being 47 feet at the highest point. Hemlock piling, hewn hemlock caps, and sawed bracings were used. There were three sets of bracing, made of 3 by 8 inch and 3 by 10 inch material.

Case 5.—The cost of building a pile-bent trestle 160 feet in length and averaging about 20 feet in height was $2.50 per linear foot. This includes the cost of yarding the material to the site and building the trestle, also a rental of $5 per day on the equipment. The bents consist of three piles, the highest point on the trestle from the ground being 20 feet. Rough hemlock timber was used for piling, caps, and stringers.

Case 6.—The cost of a pile-bent trestle 160 feet in length and having an average height of 8 feet was $2.40 per linear foot. This includes the cost of yarding the material to the track and building the trestle, and also a rental of $5 per day on the equipment. The bents consisted of three piles, the highest point on the trestle from the ground being 12 feet. Rough hemlock timber was used for piling, caps, and stringers.

Case 7.—The cost of building the following pile-bent trestle was $389.05, or $2.28 per linear foot. This total does not include the value of the timber used for piling, nor the value of the sawed caps, stringers, and bracing.

Structure.

Total length feet	170
Number of piles	39
Average length of piling feet	20
Average penetration of piling feet	10
Sawed caps	7

Sawed stringers, 8 by 16 inch Douglas fir.
Bracing, 300 feet b. m. (3 by 12 inch).
Alignment: 100 feet, 28°; 70 feet tangent.

Cost.

Moving machinery to place	$42.77
Yarding material to site	33.75
Driving piling	117.36
Placing stringers and caps	77.46
Laying track	18.50
Excavating	17.12
Surveying	19.09
Drift bolts, 200 pounds, at $2.25 per 100 pounds	4.50
Rent of equipment	58.50
Total	389.05

The cost of driving piling for pile-bent-trestle construction varies. In one case piling was driven, cut off, and capped at the rate of $1.86 per pile.

The daily cost was as follows:

Foreman	$4.00
Engineer	3.50
Fireman	2.75
3 men, at $3	9.00
Total labor cost	19.25
Rental on equipment	10.00
Total cost	29.25

Average daily output, 16 piles driven and capped.

This trestle was 2,000 feet long and consisted of three-pile bents, spaced 16 feet apart. It averaged about 10 feet in height, the penetration of the piling averaging about 15 feet.

(*b*) Frame-bent trestles are made of both round and sawed timbers. If the former material has to be brought from a considerable distance, it is advisable to use the latter, since it is easier to fit and is more durable. On the longer main-line logging roads, most of the frame trestles are built of sawed timber, the trestles on the spurs being usually built of round timbers. Not infrequently, however, the stringers used in connection with the construction of the trestles on these latter roads consist of sawed timber. Where suitable pole timber is available, a rough-timber trestle can be constructed more cheaply than one with a sawed frame.

The general appearance of a frame trestle is much the same as that of a pile trestle. The bents, which are spaced 13 to 16 feet apart, consist of four legs made of round timbers 14 inches and up in diameter or 10 by 10 inch or larger square timbers. Each bent rests upon a sill, which may be either a log or a 10 by 12 inch sawed timber. Round or sawed timbers are used for caps and stringers.

In computing the cost of frame trestles, the lumber used is commonly included at $12 per thousand feet. A convenient way of figuring the cost of any trestle is at so much per 1,000 feet of the material contained in it. This cost includes lumber, bolts, and other supplies, and the labor of building the foundations and framing the trestle. The cost of several representative standard-gauge frame trestles recently constructed on logging railroads in this region is given in Table 31.

TABLE 31.—*Cost of frame trestles.*

Length, feet.	Maximum height, feet.	Feet b. m.	Total cost.	Cost per M feet.	Cost per linear feet.
620	52	105,000	$2,800	$26.66	$4.52
652	28	60,000	1,565	26.08	2.40
762	8	68,000	1,704	25.06	2.23
202	32	28,000	743	26.54	3.68
140	34	19,000	487	25.63	3.34
238	31	31,000	724	23.35	3.04
272	41	45,000	1,030	22.89	3.77
144	54	30,000	713	23.76	4.95

TRACK MATERIALS.

The following discussion has to do with standard-gauge material.

Crossties.—Both sawed and hewn ties are used in constructing logging railroads. Where the logging operator is also engaged in the manufacture of lumber, and the sawmill is close to the logging camp, most of the ties used are sawed. Independent loggers, as a rule, use hewn ties exclusively.

Sawed ties vary in size. The usual size on standard-gauge roads in the region is 7 by 9 inches by 8 feet. Ties 7 by 8 inches by 8 feet are also used. In many cases ties 6 by 8 inches by 8 feet are used on side tracks. A large percentage of the sawed ties used in logging roads are culls.

Common-carrier roads, in purchasing hewn ties in the region, generally demand that the ties shall be made of Douglas fir and be peeled; that they shall not be less than 8 feet nor more than 8 feet 2 inches long, with the ends sawed off square; that they shall be hewn on two sides, straight and true to an even thickness of 7 inches; that they shall not be less than 6 inches, nor more than 9 inches, wide at the widest place on the face; that there shall not be less than 56 square inches at the smallest cross section; and that ties shall be made from sound, live timber, "taken out of wind," and free from splits, shakes, unsound knots, and score hacks. They will, however, accept 10 per cent of No. 2 ties, which are similar in every respect to No. 1 except that they may range from 7 feet 11 inches to 8 feet 3 inches in length and may be 50 square inches at the smallest cross section.

The specifications of hewn logging railroad crossties, here designated as No. 3 ties, sometimes provide that ties shall not be less than 7 feet 9 inches nor more than 8 feet 3 inches in length; that they shall not be less than 6½ inches in thickness; and that the width of the face at the smallest end shall not be less than 6½ inches.

In one case, a logging operator paid a contractor $0.23 per tie for making and delivering No. 1 hewn ties along the right of way, the contract providing that 10 per cent of the ties could be No. 2's. The contractor was paid $0.19 for making and delivering No. 3's along the right of way. The tie contractor sublet the contract, paying $0.11 for No. 1 and No. 2 barked ties in the string. Where the ties were hewn, barked, and sawed, the tie contractor paid $0.13 per tie. The tie makers received $0.085 for No. 3 hewn ties in the string. The ties had to be skidded an average distance of from 150 to 200 feet to the right of way. The contractors, as a rule, received about $0.16 per unbarked logging-railroad tie; that is, for making the ties and delivering them along the railroads. Ties used in the construction of logging railroads in the region are, as a rule, made of Douglas fir and hemlock, preferably the former. The above cost does not include the value of the stumpage.

The number of ties used per mile depends on the character of the roadbed, the size of the rail, the weight of the locomotives used, character of the ties used, etc. In the more or less permanent main logging railroads, 16 ties per 30-foot rail, or 2,816 ties per mile, are ordinarily used. Where the ties are small and inferior, 17 or 18 may be used per 30-foot rail. This latter is particularly applicable to the spur lines. Sometimes 14 or 15 are used per 30-foot rail.

The volume of timber in sawed ties when 2,992, 7 by 8 inches by 8 feet ties are laid per mile amounts to 111,600 feet, and 95,700 feet when the same number of 6 by 8 inches by 8 feet ties are laid. At $12 per thousand feet, the cost per mile for ties is $1,339.20 in the first instance, $1,148.40 in the second. The cost of hewn ties per mile ranges from $600 to $750.

Ties used in main-line logging railroads last seven or eight years, provided a good class of Douglas fir ties is used. Six years is a conservative figure. Ties used in spur roads do not last so long, since the operation of taking them up and relaying them is hard on them. Spur railroad ties may be used in three or four different locations, provided the total period of use does not exceed four or five years.

Steel rails.—Rails are classified according to their weight in pounds per linear yard. They are sold by the long ton. While the standard rail length is 30 feet, shippers reserve the right to include 10 per cent of from 24 to 28 foot rails in a given order.

Rails varying from 45 to 60 pounds per yard may be observed on the logging railroads in the region. Fifty-six and 60 pound rails are the more common, 60-pound on the main lines, 56-pound on the spurs. Many operators, however, use 60-pound steel on both the main line and spurs.

The use of heavy rails has paid. They depreciate less in use and in the lifting and relaying. Furthermore, they can be used with fewer ties and on a poorer roadbed than the lighter rails.

The number of long tons of rails of different weights required per mile may be found by multiplying the weight per yard by 11 and dividing the result by 7.

Example: Weight of rail, 60 pounds per yard, then $\frac{60\times 11}{7}=94$ tons and 640 pounds.

The weight in tons of several representative sizes of rails per mile is as follows:

Weight of rail per yard.	Weight of track per mile.	
Pounds.	*Tons.*	*Pounds.*
45	70	1,600
50	78	1,280
56	88	
60	94	640
65	102	320
70	110	

The following were the f. o. b. prices of steel rails in Chicago in March, 1914:

45 pounds per yard and down, $27 per ton.
50 pounds per yard and up, $28 per ton.

The freight rate from Chicago to Pacific coast terminal points is $11 per ton. In estimating the cost of the rails to be used in a given case, one should add the cost of transporting the rails from the terminal point to the camp.

In 1914, first-class relaying rails at Pacific coast terminal points were worth about as follows:

45 pounds per yard and down, $35 per ton.
50 pounds per yard and up, $36 per ton.

Second-class inspected relaying rails were worth about as follows:

45 pounds per yard and down, $29 per ton.
50 pounds per yard and up, $30 per ton.

It is customary to figure the life of steel rails at 20 years. This is, no doubt, about right for the rails used in main-line logging roads. Possibly it is too high for rails used on spurs, where the grades and curvature are heavy, the roadbed is relatively poorer, and the steel is taken up and relaid often. A life of 15 years, with a scrap value of 20 per cent of the initial cost, is thought to be a better basis for estimating the depreciation on rails so used.

Angle bars.—Either angle bars or fishplates are used to strengthen and brace the rails at the joint. The usual method is by means of angle bars. They are bolted on each side of the joint with two bolts in each rail head.

The weights of angle bars for four typical weights of rails are as follows:

Size of rail.	Weight of angle bars per pair.	Weight of angle bars per mile.[1]
	Pounds.	*Pounds.*
45-pound rail	21.5	7,675
50-pound rail	23.4	8,354
56-pound rail	28.0	10,396
60-pound rail	31.4	11,210

[1] Standard requirements call for 352 joints per mile.

The cost of angle bars f. o. b. Pacific coast terminal points in 1916 was approximately $2.05 per hundredweight. The cost of angle bars per mile for four typical rails is as follows:

Size of rail.	Cost of angle bars per mile of track.[1]
45-pound rail	$158.00
50-pound rail	172.00
56-pound rail	213.00
60-pound rail	230.00

[1] Amounts do not include the cost of transportation from Pacific coast terminal points to the right of way.

Bolts and nuts.—Four bolts and nuts are required at each rail joint. They come in kegs of 200 pounds each. The approximate price at Pacific coast terminal points is $3 per hundredweight, or $6 per keg. With hexagonal nuts, the quantity required per mile, also the cost, is as follows:

Rail.	Size of bolts.	Number in keg.	Number of kegs per mile.	Cost per mile.
	Inches.			
45-pound rail	3 by $\frac{3}{4}$	245	5.2	$31.00
50-pound rail	$3\frac{1}{2}$ by $\frac{3}{4}$	270	5.7	34.00
56-pound rail	$3\frac{1}{2}$ by $\frac{3}{4}$	270	5.7	34.00
60-pound rail	$3\frac{1}{2}$ by $\frac{3}{4}$	270	5.7	34.00

Spikes.—Rails are fastened to to the crossties by square spikes, which are usually $5\frac{1}{2}$ inches by $\frac{9}{16}$ inch under the head. Four spikes are driven to each tie, one on each side of the rails. The cost f. o. b. Pacific coast terminal points is approximately $2.50 per hundredweight, or $5 per keg. There are 400 of these spikes in a keg, and about 29 kegs are required per mile. The cost of spikes per mile of track is about $145.

Turnouts.—A turnout is a contrivance for passing from one track to another. The principal parts are the switch, the frog, and two guard rails. There are two kinds of switches, stub and split. The split switch is generally used on the logging roads because of its greater safety. A turnout for 60-pound rail, including switch, frog, guard rails, ground throw and rail braces, costs about $100. With a high stand it costs about $10 more.

STEEL LAYING AND REMOVAL.

Laying and removing the rails, as a rule, is done by hand. It is done both by contract and day labor, the latter being by far the more common practice. For several reasons it is not known just what it costs logging operators to lay and lift track. Very few operators keep their accounts in such a way as to make this information available. Then, too, this cost does not always include the same items of expense. Furthermore, conditions, wages, and efficiency of labor, etc., vary. Those desiring to secure a knowledge of cost of this work should familiarize themselves with what is said in connection with common carrier roads, bearing in mind that logging operators generally pay higher wages, secure less efficient help, and seldom work under as favorable conditions.

Track laying is here considered as the operation of loading the ties, rails, etc., on the cars, unloading this equipment, placing the ties and rails, and curving and jointing the rails. The cost of train service is not included unless it is so specified.

To lay the track costs from $250 to $325 per mile. One superintendent who has directed the building of more than 25 miles of logging railroad during the last three or four years estimates the cost of laying 1,000 feet of standard-gauge track with new steel as follows:

Rental on locomotive	$10
Train crew, fireman, and engineer	7
Foreman	4
Twelve hands, at $2.50	30
Total	51

This is at the rate of about $270 per mile.

As logging progresses, the track is lifted and relaid on new spurs. This work usually takes place at the same time. Ordinarily, track can be lifted and laid for from $10 to $12 per station, the cost of lifting by hand when both rails and ties are taken up being about the same as the laying of the track.

The cost of installing switches, when labor is paid at the rate of $2.50 per day, amounts to about $20 per switch.

The cost of surfacing, which consists of shoveling earth in between the ties, aligning the track, and tamping, amounts to about $300 per mile.

Quite often material suitable for filling between and under the ties is not at hand and has to be hauled in on cars. Foreign material, usually consisting of gravel or broken rock, is known as ballast. Whether some material other than that found along the right of way is used will depend on the formation of the roadbed, the material along the right of way, what seasons of the year the track is to be used, and the period of time the track is to be used. If a spur is going to be used only during the dry season, no rock ballast will be used. Then, too, if rock ballast is very scarce, it will not be used on spurs during other seasons of the year. The same factors apply to the amount of ballast that should be used in a given case.

In estimating the cost of surfacing with ballast one should know the character of the ground through which the right of way runs, also where ballast can be found. Where ballast is scarce and has to be hauled in at some distance the cost per mile may be considerable. The cost of surfacing the main-line logging railroad in one case amounted to $1,800 per mile; in another case, $1,200 per mile. Most operators have found that it pays to use plenty of rock, gravel, or other ballast on lines that are to be in use some time, since by so doing they reduce the cost of maintenance by more than enough to offset the cost of ballasting. Other advantages also result from a well-ballasted track.

TOTAL COST OF BUILDING LOGGING RAILROADS.

The total cost of building 4¾ miles of logging railroad in one case, exclusive of ties, steel, fixtures, and certain other items indicated in the following discussion of the cost, was as follows:

Items.	Total cost.	Cost per mile.
Engineering and superintendence	$2,012.25	$423.63
Construction, buildings, etc	60.00	12.63
Grading tools	102.76	21.63
Clearing right of way	2,295.00	483.16
Labor grading	8,824.05	1,857.70
Powder grading	1,247.57	262.65
Stringer bridges	565.50	119.05
Trestles on hill	4,623.63	973.40
Trestles at slough	4,132.00	869.89
Labor laying track	2,821.50	594.00
Labor surfacing	6,223.66	1,310.24
Total	32,907.92	6,927.98

Starting at the bottom of the hill, the first 975 feet consisted of a pile-bent trestle. Another pile-bent trestle, 2,325 feet long, branching from the main line and running in the same general direction, is included in the above cost. From the end of the first trestle the road passed along a very steep hillside, over one switchback, and around an oxbow. From the beginning to the end of the first 2½ miles of graded track the air-line distance was 1¾ miles. The last 1¾ miles was fairly light construction, the road traversing rolling ground which was swampy in places. The maximum curve was 30° and the heaviest grade (favorable) was 6½ per cent. After the top of the hill was passed there was an adverse grade of 5 per cent. The grade from the bottom to the top of the hill averaged 4 per cent.

The cost of the engineering and superintendence includes the cost of the location and supervision, the salary and expenses of the resident engineer, also the salaries of his assistants.

The preliminary work includes the cost of constructing living quarters for the laborers and pile-driving crew, also an office. Twenty-five per cent of this cost was charged against the railroad construction work. The cost of structures was as follows:

Material	$127.30
Labor	112.65
Total	239.95

The total cost of grading tools was $308.29. These tools at the completion of the work were transferred to the logging department, 33⅓ per cent of their cost, or $102.76, being charged against the grading. Practically all of the grading was done by hand.

The cost of wire rope used in yarding material along the right of way and in driving piling, blocks, hooks, peavies, pike poles, logging-engine repairs, oil, waste, grease, packing, etc., amounted to $975.17. At the completion of the road all this equipment, with the exception of lines and blocks, was transferred to the logging department, the construction department being credited with $100, leaving $875 charged against the construction work. The latter amount was written off as follows: $488 against the "hill trestles"; $427 against the "slough trestles."

The work of clearing the right of way includes the felling and bucking and swamping on the 30-foot right of way. The right of way ran through a fairly heavy stand of second-growth Douglas fir. On the hillside, about one-half the total distance, it was entirely handwork, the timber being felled clear of the right of way. The down timber on this part of the road was cut in short lengths and handled with peavies. On other parts of the lines, a logging engine was used in removing timber from the right of way. Large charges of powder were used. The cost of clearing at the trestles was not charged against the right of way, but against the trestle-constructing crews.

The cost of this work was segregated as follows:

Labor	$2,035.35
Powder	259.65
Total	2,295.00

The hand work cost about $528 per mile; the machine work about $419. The powder delivered cost about $0.105 per pound.

The following wages per day were paid:

Hand clearing.

Foreman	$3.50
Powder man	3.00
Laborers	2.00
Head fallers	3.75
Second fallers	3.40
Buckers	3.25

Machine work.

Foreman	$5.00
Engineer	3.40
Rigging men	3.00 to 3.25
Fireman	2.75

The grading work was done entirely by hand. Eliminating the bridge and trestle work, there were 3 miles and 2,834 feet of line graded; 39,402 cubic yards of earth were moved on the entire line, being at the average rate of 211 cubic yards per station. The material was classified as follows: 90 per cent of earth; 8 per cent of loose rock (a soft sand rock); 2 per cent of solid rock.

The total cost of grading was classified as follows:

Labor	$8,824.05
Powder	1,247.57
Total (3.53 miles)	10,071.62

The average cost per mile when based on 3.53 miles of actual grading was $2,853.00; when based on 4.75 miles, or the total length of the line, $2,120.34. The following wages were paid: Grading foreman, per day, $3.50 to $4; laborers, per day, $2.

There were 1,450 feet of cribbing for stringer bridges built on ground that was soft during parts of the year. The conditions were ideal for this kind of work, since the timber was long, straight, second-growth fir. The mud sills were spaced about 20 feet apart. The stringers were not barked, neither were they hewn on top.

The hill trestles, 15 in number, were frame-bent structures. In length they ranged from 48 to 224 feet; in height from 10 to 45 feet, averaging about 20 feet. Their total length was 1,656 feet. The bents were spaced 16 feet apart center to center. Hewn caps and stringers were used. The caps were 12 feet long and hewn to a 12-inch face on two sides; the stringers, 15 inches thick and hewn to an 8-inch face on two sides. The value of the stumpage included in these structures, as well as in other bridges, is not included in the cost. As these trestles were constructed on a steep side-hill, their cost was higher than it would have been on level ground. The cost was segregated as follows:

Items.	Total cost.	Cost per linear foot.
Labor	$3,567.10	$2.15
Bracing, material	378.56	.228
Spikes and drift bolts	229.80	.132
Bridge tools	448.17	.270
Total	4,623.63	2.78

The cost of the trestle at the slough does not include laying the ties and steel. The following items were segregated:

Items.	Total cost.	Cost per linear foot.
Labor	$2,187.00	$0.63
Bracing, material	70.00	.021
Drift bolts	122.00	.037
Piling, caps, and stringers	1,242.00	.373
Brow skid straps	84.00	.025
Tools	427.00	.127
Total	4,132.00	1.213

The above includes the cost of building 3,300 feet of 3-pile bent trestle, together with a 300-foot log dump, the driving of the piling, hewing and placing the caps and stringers, and the cost of the material. The trestles averaged about 8 feet in height, the bents being spaced 15 feet apart. The penetration of the piles was about 15 feet. Five thousand feet of lumber were used in the bracings, which cost $14 per thousand feet; 41,400 feet of piling, caps, and stringers were used, which cost $0.03 per linear foot delivered along the right of way.

The cost of labor for laying track was high, because 85 per cent of the line consisted of heavy curves with short tangents between. Fifty-six-pound steel was used. About 3,000 ties were laid to the mile. All bridges were double guard-railed; all curves single guard-railed. The foreman was paid $3.50 per day; the laborers, $2 per day.

The track was surfaced with from 12 to 15 inches of broken-rock ballast. This was blasted out of a pit, broken, and loaded by hand, so that it was very expensive.

MAINTENANCE OF WAY.

Section screws are employed to keep the road ballasted up, maintain the gauge, keep the ditches open, replace broken or decayed ties, and to make any other repairs that are necessary. The cost of this work per thousand feet depends on several factors. The following are the most important:

(*a*) The cost per 1,000 feet is higher the greater the length of line in use.

(*b*) The volume of timber hauled per year is a factor which operators can very easily overlook at the start, and which market conditions may make it difficult to control during the life of the operation. Ordinarily operators arrange for sufficient timber to enable them to write off the cost of railroad construction economically. The supply of timber does not, however, automatically take care of the maintenance of way, since this cost is distinct from railroad construction. While an exceedingly heavy traffic possibly requires more of an expenditure to keep a railroad in condition, there is no question that a small volume of traffic requires more proportionately. Because of this, the tendency is to increase the annual cut as the length of haul increases. Moreover, the recognition of this fact by the industry is one of the reasons why operators continue to run after market conditions suggest that they should close down.

(*c*) The maintenance cost in some cases is unnecessarily high because the road was poorly constructed in the beginning, the result being that the construction of the road really continues throughout the life of the operation. The tendency at the present time is to build better logging railroads.

(*d*) The principal part of the maintenance of way is the labor of section crews. Ordinarily five men under a section foreman should keep 6 miles of main line logging railroad in good condition.

With the exception of a small expenditure for tools and rail fastenings, the rest of track maintenance is made up of tie replacements. The life of ties is taken up in the discussion headed "Track materials" in this section.

EQUIPMENT.

The equipment in the main consists of locomotives and cars or trucks.

(1) *Locomotives.*—There are two general types of locomotives used, rod or straight connected, and geared. The type used in a given case is determined largely by the grades and curvature of the road.

The rod engine is universally used on the common carrier railroad. In it the power is transmitted from the cylinders to the drivers by means of a connecting rod. Rod locomotives have a longer wheel base than geared locomotives, and so can not take as sharp curves. They make better time, however, and cost less for maintenance, proving the most satisfactory type on relatively long hauls and where the road is smooth, well maintained, and of easy grade. To secure good service with a rod engine, the maximum grade empty should not exceed 3 per cent; the maximum grade loaded, 1½ per cent. However, there are a number of rod engines working on roads having grades of 5 per cent. The maximum curves permissible are about 25 degrees.

A special form of rod locomotive is used to a limited extent in the region. Its essential features are two sets of engines mounted under the boiler, each connected to two independent groups of drivers. This has the effect of materially shortening the wheel base, permitting the use of heavy rod locomotives on roads having curves that are too sharp for the regular type of rod locomotive of the same weight. It is claimed that this engine can start greater loads than the ordinary rod engine of the same weight. One weighing 121 tons is operated on a road having 35-degree curves and 8 per cent grades. There are several makes of rod locomotives on the market.

Bryant, in "Logging," states that the first geared locomotive was constructed about 1885 by E. E. Shay, a Michigan logger; and this type of locomotive, with some modifications and improvements, is in extensive use to-day. Two other forms of geared locomotives are now in use in the region.

Most of the locomotives used in logging in the region are of the geared type. This is because sharp curves, heavy grades, and relatively rough roadbed, which the geared locomotive is designed to overcome, are characteristic of logging railroads. Geared locomotives may be observed working on main-line logging railroads where the grades are 2 per cent for loaded trains and 5 per cent for empties, and on spurs where the grades are as high as 7 or 8 per cent, or even 10 per cent on short stretches for empties and 5 per cent for loaded trains.

With the geared locomotive, every wheel under the locomotive and tender is a driving wheel, the wheels being arranged in pairs on swivel trucks. The trucks are connected one with another by an articulating shaft, the power being transmitted to the driving wheels through a series of bevel gears. This arrangement gives a maximum amount of tractive force with a minimum total weight, a short-truck base, and a form of truck that will readily adjust itself to an uneven track. There are two types of geared locomotives; namely, the center shaft and side shaft.

The weight of the locomotives used in the region varies, dependin on the maximum grades and maximum loads. In the case of the rod engines, the total weight ranges from 42 tons or less to 120 tons. The larger engines are used for long hauls. The weight of the geared locomotives ranges all the way from 42 tons or less to 100 tons. Most of these locomotives, however, range from 42 to 60 tons, 42 and 50 ton locomotives being used on the spurs, 60-ton locomotives on the main lines. Locomotives of the latter weight are also used on the spurs.

The hauling ability of a locomotive depends largely on the tractive force, the frictional resistance, and the resistance of the road to gravity. The tractive force is the power for pulling a train, including its own weight, and amounts in pounds, as a rule, to from 20 to 23 per cent of the total weight on the drivers. The resistance due to friction varies with the character and condition of the roadbed and rolling stock. Logging cars of good construction and with well oiled bearings should have a rolling friction of from 12 to 20 pounds per ton of weight handled. Where the conditions are first class, this will not be too high; but if the roadbed is poor and the journals are not well oiled, the rolling friction may be as much as 25 or 30 pounds. The frictional resistance due to curves is extremely variable, since it is governed by so many factors, of which the degree of curvature is the principal one. It is the general rule to assume the resistance due to curves for standard gauge to be one-half pound per ton per degree. The grade resistance is 20 pounds per ton for each 1 per cent of grade.

The hauling capacity of a locomotive, in tons of 2,000 pounds, is determined by dividing the tractive force of the locomotive by the sum of the resistance due to gravity, rolling friction, and curve resistance, and then deducting from this result the weight of the locomotive and tender. The estimated hauling capacity of given weights and types can usually be found in catalogues of manufactures. In Table 32 the estimated hauling capacity of rod and geared locomotives is given.

The approximate cost in 1914 of rod and geared locomotives at Pacific coast terminal points was as follows:

TABLE 32.—*Cost, weight, and capacity of engines.*

ROD.

Weight.		Hauling capacity (exclusive of engine and tender).				Cost.
Total.	On drivers.	Level.	1 per cent.	3 per cent.	4 per cent.	
Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	
42	31	1,240	415	140	90	$9,500
55	40	1,630	545	185	125	11,200
67	49	1,970	665	225	150	13,900
71	57	....	....	....	....	14,500

GEARED.

Weight in working order.	Hauling capacity (exclusive of engine and tender).[1]								Cost with air brake.
	Grade.								
	Level.	½ per cent.	1 per cent.	2 per cent.	3 per cent.	4 per cent.	5 per cent.	6 per cent.	
Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	
24	1,312	570	357	198	133	97	74	59	$5,670
28	1,550	673	422	235	158	116	90	72	6,490
32	1,740	757	476	265	179	132	102	81	7,040
36	1,815	788	493	273	183	133	102	81	7,910
42	2,071	900	563	311	207	151	115	91	8,260
50	2,497	1,083	679	377	252	184	141	112	9,450
60	2,922	1,266	793	438	292	212	162	127	10,610
70	3,698	1,591	990	554	372	271	209	166	11,890
80	4,301	1,868	1,169	648	434	317	242	192	14,980
90	4,965	2,160	1,360	755	508	374	289	230	16,090

[1] Hauling capacity given is calculated on an assumed rolling friction of 8 pounds per ton.

These prices do not include oil-burning equipment, which can be installed for from $400 to $500 per boiler. For shipment to the Pacific coast all locomotives under 42 tons in weight are loaded on flat cars, and the freight rate is $1.50 per hundredweight. Larger locomotives are shipped on their own trucks at a rate of $0.88 per hundredweight, plus $200 for a messenger to accompany the engine. For 32-ton to 80-ton locomotives the shipping weight is from 5 to 8 tons less than the working weight.

It is not possible to state the maintenance cost of locomotives, because it depends on so many factors. One logging superintendent is of the opinion that it ranges between $600 and $1,000 per year. He stated that the upkeep of three locomotives, 18, 36, and 42 ton, during the last year of operation amounted to $2,425, and that the upkeep of a 60-ton engine, which averaged 60 miles per operating day, amounted to $1,121 during this year. Another logging superintendent estimated the maintenance cost per year of locomotives as $600 for rod and $1,100 for geared.

The following data, based on four years' time, were furnished by a logging superintendent. The information has to do with four geared locomotives, one 60-ton and three 50-ton.

Maintenance cost of locomotives.

Year.	Number of locomotives.	Total yearly cost.	Average cost per locomotive.	Total amount timber hauled (feet).	Average amount timber hauled per locomotive (feet).
1908	4	$1,540	$385	28,000,000	7,000,000
1909	4	1,620	405	27,000,000	6,750,000
1910	4	3,000	750	40,000,000	10,000,000
1911	4	1,100	275	38,000,000	9,500,000
Total		7,260			
Average		453			

If locomotives have the proper kind of treatment, the maintenance cost per year will probably range from $400 to $700 for geared locomotives and from $300 to $400 for rod locomotives.

The service demanded of locomotives on logging railroads is usually severe, the result being a relatively short life. For the purpose of a timber appraisal, the life of rod locomotives used on a main-line logging railroad may be placed at 20 years, the life of geared locomotives at 15 years. If the work to be done by the latter type is particularly trying, 12 years should be used.

Cars.—Three types of log cars are used in the region; namely, flat cars, skeleton cars, and separate trucks.

Flat cars are not used to any extent except where the logs are hauled over a common-carrier railroad, in which event the cars are not owned by the logging company. Of course, all logging companies have three or more for use in connection with construction work, etc. There are a number of makes and sizes on the market. The standard low logging flat car, built in the region, is 41 feet long and accommodates 42-foot logs. It has a capacity of 80,000 pounds, weighs 26,700 pounds, and costs about $850 f. o. b. Seattle. When equipped with very satisfactory patent bunks and chocks it costs about $925.

The skeleton car consists of two pair of four-wheel trucks joined together by heavy timbers, and is very satisfactory where it is desirable to use air brakes. One make, which is used as much as any, costs about $750 f. o. b. Seattle. This price includes air equipment, also patent bunks and chocks and automatic couplers. The car is built in lengths up to 56 feet over all, has a capacity of 80,000 pounds, and weighs about 19,000 pounds.

In most cases where the logs are not hauled over common-carrier railroads, disconnected trucks are used. There are a number of makes and sizes on the market. One truck, which is used as much as any, cost about $750 per set f. o. b. Seattle in 1913. This price includes patent bunks and chocks, also automatic couplers. Each truck is equipped with chains for binding on the logs. These chains cost about $20 extra per set of trucks.

The number of cars required varies considerably. Where the output amounts to from 175,000 to 200,000 feet per day, the number ranges from 25 to 60 or more. The number required for a given operation depends on the following:

(1) The amount of timber handled daily. (2) The volume of the average load, which runs from 6,000 to 8,000 feet. (3) The average number of cars hauled per trip. (4) The method of loading. If it is possible to store logs on the landing without interfering with the operation of transporting the logs from the stump to the landing, a smaller number of cars may be employed than where the logs have to be loaded practically at the time they are delivered at the landing. (5) Method of unloading. The longer it takes to unload the logs, the greater the number of cars required. (6) The distance that the logs have to be hauled, also the number of divisions the road is divided into.

For the purpose of a timber appraisal, the maintenance cost of flat cars may be placed at about 10 per cent of the purchase price; skeleton and disconnected trucks, at about 6 to 8 per cent of the purchase price. The life of flats and trucks may be figured at from 10 to 12 years. If they are kept in proper repair, their life will be much longer than this.

OPERATION.

Under this heading will be discussed the cost of transporting logs from the landings to the dump. The elements of cost are the same as for yarding, loading, etc.

A general idea of the operation of logging railroads has been given. The labor required, as well as the amount of equipment, depends upon the daily output, length of haul, grades, etc. In some operations one locomotive is sufficient. This engine hauls the empties out to the woods, switches them to the landings, picks up the loaded cars, and hauls them to the dump. Larger operations with longer main lines require a locomotive in the woods distributing the empties and switching out the loaded cars to a point where they can be picked up by the main-line locomotive. Still larger operations require four or five locomotives. If the output is large and the haul long, two of them may work on the main line.

The number of locomotives and train crews employed should be ample to keep plenty of empties available at the landings, since delays in the yarding and loading department caused by waiting for cars materially increase the cost of these steps in the operation.

The average volume of timber hauled from the landings to the dump per locomotive per day seldom amounts to less than 50,000 feet or more than 100,000. Taking it straight through the region, the average output of timber per locomotive per day amounts to about 75,000 feet. It should be borne in mind, however, that average figures of this character are of little value.

To get an estimate of the number of cars and locomotives to be used, which has a direct bearing on the items of depreciation, replacements, maintenance, supplies, and labor, the timber appraiser works roughly as follows:

The total amount of timber included in the sale, the period allowed for the removal of the timber, and the length of the cutting season fix the average amount that should be logged daily. Whether the transportation of this amount will require the services of one, two, three, four, or more locomotives is the next thing to be decided. If a proper field examination has been made, the appraiser knows the approximate lengths of the different hauls during different periods of the operation, also the approximate rise and fall on different sections of the track, which information will determine the type and weight of the locomotives to be used. The appraiser then estimates the number of locomotives or the number of train crews. In a given case he may decide that one locomotive will be ample for the first two years; that after the second year two will be required; and that after the fourth year three will be required. In this way he arrives at a basis for estimating the labor and other costs per thousand feet for operating the trains.

In connection with the above it should not be forgotten that locomotives lose considerable time each day in switching, unloading, taking on fuel and water, etc. A geared locomotive may be run at the rate of 12 miles or more per hour on ordinary logging railroads, so that it would seem that they should travel 60, 70, 80, or more miles per day. Seldom, however, do they do this, 25 to 35 miles being good work for a locomotive working on spurs or relatively short main lines. Not infrequently they do less than this.

Most operators charge to "Railroad operation" the cost of hauling men to and from their work, hauling rails, ties, ballast, etc., used in constructing and maintaining the railroads, hauling water to logging engines, etc. It is perfectly proper to charge them under this heading or under a special heading. From the standpoint of a timber appraiser, the main thing is that in estimating the cost of railroad transportation he has to consider the amount of track to be built, the amount of material to be used for ballast, whether portable or stationary camps are used, and whether water for the logging engines will be hauled, pumped, or supplied by a gravity system.

Labor cost.—A train crew is generally made up of an engineer, fireman, conductor, and brakeman. For a long train two brakemen may be employed.

The following list is intended to approximate the wages—average, high, and low—paid the members of the train crews by the logging companies in the region during the past six years:

Position.	Wages per day.		
	Average.	High.	Low.
Locomotive engineer	$4.00	$4.50	$3.75
Fireman	3.00	3.25	2.75
Conductor or head brakeman	3.50	4.00	3.25
Brakeman	3.25	3.50	3.00

The average cost per thousand feet varies greatly. For example, the labor cost per thousand feet for the operation of trains at 20 camps in the Puget Sound region in 1913 was as follows:

Number of camps:	Cost per 1,000 feet.
2	$0.10–$0.15
4	.15– .20
10	.20– .25
1	.25– .30
1	.31
1	.40
1	.50

Fuel.—A very considerable item in the cost of operation of logging railroads is the cost of fuel burned in the locomotives. The fuel may be wood, coal, or oil. Wood, as a rule, is not used when coal or oil can be secured at a reasonable price.

On account of the danger of setting fire with sparks from wood or coal, oil makes the most satisfactory fuel. In many cases it is also cheaper. It does not take so long to take on oil as wood or coal, which means a saving of some operating time. Then, a saving in fuel and water is effected, particularly on heavy grades, and the hauling ability is increased, because the steam pressure can be held at a desired point by increasing the oil feed under the boiler. It is not possible to do this with wood or coal, since merely opening and closing the fire box has a marked effect on the efficiency of the locomotive under strained conditions. While bituminous coal is possibly no more satisfactory than wood from the standpoint of the fire risk, it is preferred to wood when it can be secured at a reasonable price. Firemen prefer it because the labor of firing it is not so exhausting. A more even fire can be maintained with it, and less time is lost in taking on coal than wood.

The relative value of the three kinds of fuel is approximately as follows:

One ton of good grade bituminous coal is equivalent to 1½ cords of oak wood or from 2 to 2½ cords of soft wood, and from 130 to 190 gallons of crude oil. For example, in one case 1 ton of coal did the work of 3 barrels of oil. The distance from the camp to the dump was 20 miles. A 60-ton locomotive made two trips per day, the total distance traveled amounting to 80 miles. When hauling 120,000 feet per trip, 6 tons of coal costing $4.25 per ton were consumed per day, and when hauling the same volume of timber per trip 18 barrels of oil, costing $1.10 per barrel, were consumed, a saving of $4.50 per day resulting from the use of oil.

The amount of fuel consumed daily by logging locomotives is extremely variable, depending on the mileage traveled, the loads hauled, the number of heavy grades encountered, and the efficiency of the fireman. Roughly, a logging locomotive burns from 150 to 200 pounds of coal per mile, 150 pounds when the grades do not exceed 2 per cent, 175 pounds when the grades range between 2 and 5 per cent, and 200 pounds when they exceed 5 per cent. These approximations are based on a 50-ton geared locomotive making about 36 miles per day. Using these figures and assuming that 1 ton of coal is equivalent to 3 barrels (126 gallons) of oil, a locomotive burns about 9½ gallons of oil per mile when the grades do not exceed 2 per cent, 11 gallons when the grades range between 2 and 5 per cent, and 12½ gallons when the grades exceed 5 per cent. On the same basis a logging locomotive will burn from 5 to 8 cords of split wood per day.

The cost of oil is discussed under "Ground yarding." Coal delivered costs from $4 to $5 per ton. Split wood costs from $1.75 to $2.50 per cord when cut into 22-inch lengths and delivered along the track.

Miscellaneous costs.—The cost of lubricants, waste, etc., amounts to from $0.01 to $0.02 per thousand feet.

MAINTENANCE OF LOCOMOTIVES AND CARS.

Repairs to locomotives and cars are made by the blacksmith and machine shop department or by some one connected with it. This department also repairs the logging engines and other equipment. Of course, some repairs are made on this equipment by the operating crew. Operators prefer to make the heavy repairs during the slack seasons or during shutdowns.

Investment in shops.—The investment in the blacksmith and machine shops ranges from $1,000 to $8,000. Ordinarily it amounts to from $4,000 to $5,000. In many cases these shops suffice for both the mill and the logging camp.

Cost.—The cost of the repairs on shop equipment is taken up in the discussion of equipment in this section.

The shop crew ranges from two to seven men. In one large camp having relatively elaborate shops, the crew was as follows: Master mechanic, machinist, car tinkerer, blacksmith, blacksmith assistant, and carpenter.

The following list is intended to approximate the wages paid in the region to the members of this crew during the years 1911–1916:

Position.	Wages per day.		
	Average.	High.	Low.
Master mechanic	$4.50	$5.00	$3.50
Carpenter	3.50	5.00	3.00
Car tinkerer	3.00	3.25	2.75
Blacksmith	3.75	4.00	3.50
Blacksmith assistant	3.00	3.25	2.75

TOTAL COST OF RAILROAD TRANSPORTATION.

The following gives the total cost of railroad transportation in a few specific cases. In each case the costs are based on a year's output. These cases will serve to show what the total cost consists of, how it varies and why, also the way the items are segregated in the most satisfactory cost statements.

CASE 1.—*Cost of railroad transportation.*

Items.	Cost per thousand feet.
Operation (labor)	$0.275
Maintenance of line (labor)	0.268
Maintenance of locomotive and trucks (labor)	.122
Maintenance of trucks, repair parts, and materials	.04
Maintenance of locomotives, repair parts, and materials	.05
Sand (labor)	.008
Supply house (labor)	.01
Engineering (supplies)	.001
Fuel oil	.10
Oil, waste, and grease	.025
Depreciation on main line grade	.10
Depreciation on track supplies	.06
Railroad construction spurs	.283
Total	1.342

The average railroad haul from the landing to the dump was about 4 miles. The first 3 miles was over the main line, the rest over the spurs. The grade on the main line, with the exception of a short stretch, was favorable, averaging about 4 per cent. In places the favorable grade was more than 4 per cent, running as high as 8 per cent for a short distance at one point. There was about 700 feet of adverse grade on the main line, which averaged about 4 per cent.

The cost of constructing the spur lines was below the average, since the surface of the country was relatively smooth and little down timber and brush had to be contended with. The soil, however, drains poorly, which made it necessary to ballast most of the spur railroad with rock ballast. This had to be blasted out of solid rock, broken up by hand, and hauled about 2 miles upgrade. When ballast was not used, the upkeep of the spurs was abnormally high.

A 45-ton geared locomotive worked between the camp and the dump, about 3 miles, hauling about 6 loads per trip and making about 6 trips per day. A 45-ton geared locomotive hauled on the spurs, bringing in three loads at a trip. The spur railroad hauls, of course, varied in distance, but the average haul was about 1½ miles. The adverse grades on these lines did not exceed 4 per cent. A 24-ton rod engine was used to haul the men to and from their work; also to haul supplies, ties, steel, oil, etc.

The cost is based on a year's output of 50,300,000 feet. A portion of the salaries of the foreman, bookkeeper, and timekeeper, and all the salary of the civil engineer, are prorated against the labor cost.

(*a*) Operation (labor): Three locomotives were operated, with train crews as follows:

	Per day.
Engineer	$5.00
Fireman	3.25
Head brakeman	4.50
Second brakeman	3.75
Engineer	5.00
Fireman	3.25
Brakeman	4.50
Fireman	2.75
Engineer	3.25

The tracks, main and spur, were kept in better condition as to surface and alignment than is ordinarily the case. No great amount of time was lost in unloading, a train of six cars being unloaded in about eight minutes on the average, sometimes in five minutes. The main locomotive traveled about 36 miles per day and the one on the spurs about 30 miles. From 200,000 to 225,000 feet of timber was hauled per day. The volume of the average load was 5,000 feet.

(*b*) Maintenance of line (labor): This segregation includes the labor cost of keeping all railroads in good condition as to surface and alignment, keeping ditches open, and taking care of slides. It also includes the cost of considerable ballast. The total mileage maintained at any one time did not exceed 5½ miles, so that the cost of this work seems excessively high. It should be explained that the main line was used for the first time at the beginning of 1917 and that several rather large slides occurred during the year.

(*c*) Maintenance of locomotives and trucks (labor): This segregation includes the labor cost of repairing the three locomotives already described and 33 sets of trucks. The upkeep of the engine used on the spurs was very high because the engine was not built for the service demanded of it. It was of an early type, having a very light driving shaft, which caused a number of breakdowns during the year.

The regular machine and blacksmith force consisted of the following:

	Per day.
Blacksmith	$5.00
Blacksmith's helper	3.25
Mechanic	5.00
Car tinkerer	3.25

During a part of the year, a mechanic assistant and a carpenter were employed; then, too, when a locomotive was in the shop, the train crew assisted with the repairs. It should be stated that the blacksmith and his assistant spent a large part of their time in repairing logging equipment, such time being charged against the cost of upkeep of such equipment.

(*d*) Depreciation on track supplies: This segregation includes the depreciation on ties, steel rails, bolts, nuts, spikes, rail braces, tie plates, angle bars, etc.

CASE 2.—*Cost of railroad transportation.*

Items.	Cost per thousand feet.
Operation (labor)	$0.19
Maintenance of line (labor)	.188
Maintenance of locomotives, cars, and trucks (labor)	.155
Maintenance of locomotive repair parts and materials	.06
Maintenance of cars and trucks, and materials	.05
Fuel oil	.10
Oil, waste, grease, and packing	.02
Depreciation on main-line construction	.09
Depreciation on track supplies	.04
Ties	.04
Spur railroad construction (labor)	.29
Spur railroad construction (powder)	.03
Total	1.253

The year's output on which this cost is based was 37,788,000 feet, the average output per day amounting to about 150,000 feet.

A portion of the salaries of the foreman and bookkeeper, and all the salary of the civil engineer are prorated against the labor cost.

Two geared locomotives, one 33 and one 42 ton, were used to haul the logs and do miscellaenous work about the camp, including railroad construction. The haul from the landings to the dump and the camp (buildings) had practically a water grade, the 42-ton locomotive at times handling 18 loads over this portion of the road. The average grade on the two miles of main line between the camp and Spur 1 (woods' terminus of main line) averaged 5¼ per cent, the maximum grade amounting to 6 per cent. The 42-ton locomotive pulled four empty flats from the camp to the siding. The heaviest grades on the spurs amounted to 9 per cent. The average spur haul from the landings to the main line was about 1 mile. Twenty flats (length, 41 feet; capacity, 80,000 pounds) and six sets of trucks were used. Oil was burned as fuel.

The 42-ton locomotive worked on the main line between the dump and Spur 1, a distance of about 5 miles; the 33-ton engine worked on the spurs. In the morning the 33-ton locomotive would move four empty flats from the camp to the siding at Spur 1. The 42-ton locomotive averaged four or five trips per day between the dump and the siding at the camp, and roughly twice as many trips between the latter siding and the siding at Spur 1. The two brakemen, with the assistance of a man regularly employed at the dump, unloaded the cars with log jacks.

(*a*) Operation (labor): The train crews consisted of the following:

	Per day.
42-ton:	
Engineer	$5.00
Head brakeman	4.25
Second brakeman	3.75
33-ton:	
Engineer	4.50
Head brakeman	4.75
Second brakeman	3.75

The difference in the wages was not due to differences in the work, but rather to length of service with the company.

(*b*) Maintenance of line (labor): This segregation includes the labor cost of keeping all roads in good condition as to surface and alignment, keeping ditches open, taking care of slides, and hauling and digging gravel. It includes the upkeep of about 6 miles of line. During the year a large portion of the track was ballasted with gravel, the ballast being secured from the bed of a river with a power scraper. There are a large number of heavy cuts, and the formation is such that slides occurred frequently during the west season.

The section foremen were paid $3.50 per day; the hands, $2.50 per day.

(*c*) Maintenance of locomotives and cars (labor): This segregation includes the labor cost for repairing 2 locomotives, 20 flat cars, 6 sets of trucks, and 2 gravel cars.

The regular machine and blacksmith crew consisted of the following:

	Per day.
Blacksmith	$5.00
Blacksmiths' helper	3.50
Machinist	5.25
Machinist's helper	3.25
Car tinkerer	3.25
Carpenter	3.50
Second carpenter	3.00
Rigging man	3.40

This crew, in addition to repairing the locomotives, flat cars, and trucks, made the repairs on the logging equipment, the labor cost of which was $0.077 per thousand feet.

CASE 3.—*Cost of railroad transportation.*

Items.	Cost per thousand feet.
Operation (labor)	$0.12
Maintenance of trucks (labor)	.018
Maintenance of locomotive (labor)	.01
Spur construction and maintenance (labor)	.262
Maintenance of trucks (labor, repair parts, and materials)	.02
Maintenance of locomotive (labor, repair parts, and materials)	.015
Fuel wood	.05
Oil, waste, grease, and packing	.01
Depreciation on equipment and track supplies	.14
Miscellaneous	.03
Log freight	1.25
Total	1,925

In this case it was possible to locate the railroads practically any place without encountering heavy grades, since the ground for the most part is relatively level. The spur lines were ballasted and kept in good alignment.

The company had been operating about 3 years and at the time the above costs were secured had a cut of about 7 years ahead.

The year's output on which these costs are based amounted to 50,000,000 feet.

(*a*) Operation (labor): This segregation includes the cost of operating a 52-ton geared locomotive on the spur lines, hauling the logs from the landings to a siding at the camp. The logging engines were working on two spurs: one about 1 mile from camp, the other two about 2 miles from camp. To take care of the output of the camp, which was about 240,000 feet per day, it was necessary for the train crew to work overtime. The logs were hauled from camp to Puget Sound, a distance of about 12 miles, by contract, at a rate of $125 per thousand feet This rate included the cost of dumping, sorting, and rafting. The train crew consisted of the following:

	Per day.
Engineer	$4.00
Fireman	3.25
Brakeman	4.00

(*b*) Maintenance of trucks: This includes the maintenance of 56 sets of trucks.

RAILROAD INCLINES.

Inclined tracks for lowering logs are becoming an important engineering feature of logging operations. They have been used a long time in the region, but only in connection with short inclines of light grades and where ordinary logging engines furnished the power to raise or lower the roads. It is only within the past six years that operators began to consider it practical to lower loaded cars for long distances over heavy grades and with specially constructed equipment.

Heretofore large bodies of timber standing on plateaus or on mountain sides high above the main-line railroad were reached by a series of switchbacks or detours. If the amount of timber did not make such a railroad practical, chutes were used. In either case the expense of moving the timber was large. At the present time long inclines are used to transport logs from plateaus to the lower levels, the incline in such cases connecting two systems of railroads, one on the plateau and the other on the flat below; or to lower logs cut on mountain sides, such inclines running practically straight up the slope, with lateral spurs radiating from them.

The roadbed of inclines does not demand the heavy construction required where trains pass, because there is no pounding action such as is produced by a locomotive. An uneven grade is not a serious handicap unless there are portions where the grades are so gentle that cars will not be pulled to the foot of the incline by gravity. While it is desirable that inclines be built in a straight line, it is not strictly essential.

There are two systems of inclines in use; the one-way incline, in which one or more loaded cars are lowered on the down trip, the empties being returned on the up trip; and the counterbalanced system, in which a loaded car descends as the empty car ascends.

COUNTERBALANCED INCLINE.

The first long railroad incline to be used in a logging operation on the Pacific coast is of the counterbalanced type. This incline was put in operation in 1912, and it is still the longest incline in use in the region. It has a length of 8,000 feet and a fall of 3,100 feet, which means that the grade averages 45 per cent. The grade is very uneven, varying between a maximum of 78 per cent and a minimum of 10 per cent.

Another incline of this type was put in operation in Washington in 1914. A brief description of this incline and the method of its operation follow:

From the sawmill the logging railroad follows a valley for a distance of 2½ miles on a broken grade, the maximum grade being 3½ per cent. At the incline end of the railroad there is a 1,600-foot tangent, which breaks into a 24-degree curve. This curve connects with a short stretch of tangent track which forms the foot of the incline. At the foot of the incline there is a passing track for the storage of empty cars. This track, being connected with the main line at two points and having a 4 per cent grade, permits the empties to be dropped out on the main line toward the incline by gravity.

The incline is 5,300 feet long and straight for its entire length. It has a vertical rise of 1,500 feet, the maximum grade being 56 per cent, the minimum 15 per cent. The latter grade occurs at the passing point.

Starting at the bottom of the incline, there is a single track until the passing point is reached. From this point to the top of the incline there is a double track. At the upper end of the incline the tracks are laid 6 feet 8½ inches apart, center to center, except at the passing point in the middle of the incline, where they are 12 feet apart, center to center. This arrangement insures ample clearance for the rope and permits the transportation of camp buildings, logging engines, and other equipment, up or down the incline, on cars.

At the top of the incline there is a gravity siding on which the empties run. This siding branches from the incline proper and runs along below the logging road for a short distance before connecting with it.

The hoisting line passes through sheaves on the top of a tower or headworks set at the top of the incline near the hoisting engine. These sheaves, six in number and set tandem, equalize the strain on the line. The sheaves are not overloaded, each one being calculated to carry a load of 2,000 pounds, one-sixth of the downward pressure of the line at this point.

The lowering engine is located 350 feet back from the head of the incline and 250 feet from the headworks. It is mounted on a 55-foot sled, which is set level in a pit. A timbered bulkhead is set between the front end of the sled and the dirt wall of the excavation. The runners of the sled, together with the hold-down weights for the brakes, are embedded, thus insuring a very substantial setting.

The hoist consists of a large gypsy drum, equipped with suitable brakes to control the load in its descent, the motive power being furnished by 11 by 13 inch engines of the reversible type. It is equipped with two sets of gears, one set having a gear ratio of 5 to 1, the other 15 to 1. This arrangement gives a high speed—900 feet per minute—

when loaded cars are descending the incline, and a low speed for pulling up locomotives, yarding engines, etc. There are two sets of brakes—one operated by hand, the other by steam. This minimizes the danger of losing control of the load. Both brakes have tremendous holding power. The steam brake is so arranged that in the event of the steam line's becoming disconnected, the brake would be automatically thrown on, thus stopping the engine. This function of the brake is controlled by a 1,400-pound weight. In other words, when the engine is cold the brake is set, it being necessary to use steam to lift the weight. The hoist is strongly made throughout, weighs approximately 35 tons, and costs $6,500 f. o. b. Portland.

The lowering line is wrapped around the gypsy four times, so that either end can be moved up or down the incline. It consists of 1½ inch Warrington construction wire rope, which has an approximate strength of 98 tons. The stress on the rope in operation amounts to about 29 tons, giving a factor of safety of 3.35. A lubricant, consisting of pine tar and skid oil, is applied to the line three times a week. This keeps the line in good condition and greatly prolongs its life.

It has been pointed out that this line leads through sheaves on a tower at the head of the incline. To reduce further the friction and wear on the line, suitable rollers—10 in number—are placed at points where heavy breaks in the grade line occur and where the line comes in contact with the ground. These rollers are made of manganese steel, with the ends higher than the center, to keep the line traveling in the center of the track.

In hooking the load to the incline cable, a bridle with a choker hook spliced in each end is placed over the load. A long strap with an eye splice in each end is then passed under the load, through the chokers of the bridle, and back over the draw head of the flat car. A heavy clevis is used to fasten the incline cable to the bridle. To do away with any side pull that may result from the tightening of the cable, a short piece of chain is fastened around the draw head over the bridle ends. This brings the incline cable pull to the center of the track. If this were not done, the line would not travel in the same place each time, and so it would be impracticable to place track rollers.

Electric bells, located at the top and bottom of the incline, are used for a signal system. These are supplemented by telephones at the bottom, at the passing track in the center of the incline, and in the lowering engine house, thus affording communication for the entire length of the line and increasing to a great degree the efficiency and safety of the operation.

The operation of the incline is briefly as follows: A 9¼ by 10-inch yarding engine, located about 75 feet from the hoist from which it receives its steam, hooks on to an incoming load and spots it on the incline proper. This spotting engine also kicks the empties over the switch and upon the gravity spur track. The descending load brings up the empty car—standard Northern Pacific flats—their passing taking place at the middle of the incline. The load is under brake control for the entire distance, it being necessary to use steam only at starting. A trip from the headworks is made in six minutes. A daily output of 50 cars, or 250,000 feet, could be readily handled over the incline in a 10-hour working day, this being at the rate of five cars per hour, or one car in twelve minutes.

The total cost of the incline—construction, installation of equipment, equipment, etc.—was approximately $22,250. This cost may be itemized as follows:

1. Cost of clearing right of way for incline proper and gravity sidings, top and bottom, also site for headworks and hoist	$500
2. Cost of grading right of way	2,000
3. Cost of laying and surfacing track, dirt ballast was used	800
4. Cost of headworks, including labor, material, equipment, etc	150
5. Cost of installing hoist, including labor and material, etc	1,000
6. Cost of ties	900
7. Cost of steel and fixtures (60-pound steel, at $40 per ton)	4,200
8. Cost of track rollers	400
9. Cost of lowering line (5,800 feet of 1½-inch line)	3,200
10. Cost of lowering engine, f. o. b. Portland	6,500
11. Engineering	500
12. Miscellaneous (labor, equipment, freight, etc.)	600
13. Spotting engine (second hand) with equipment	1,500
Total cost	22,250

The cost of operation, including depreciation, maintenance, supplies, etc., is estimated as below. In this estimate it is assumed that 125,000 feet of timber is handled daily over the incline.

	Cost per 1,000 feet.
Labor (includes an engineer at $3.75, a hooker and unhooker at $3.00, and a chaser at $2.75	$0.10
Maintenance of grade and ties (labor and material)	.02
Maintenance of lowering engine	.01
Wire rope	.05
Fuel	.04
Lubricants	.01
Depreciation on improvements	.06
Depreciation on hoist, steel, and other equipment	.04
Miscellaenous	.01
Total	0.34

ONE-WAY INCLINES.

There are two classes of one-way inclines: The single-line system and the two-line system.

SINGLE-LINE SYSTEM.

The single-line system has been most used by logging operators on short inclines. That it is adapted for rather long hauls, however, is indicated by the following:

An operator was confronted with the problem of opening up a body of timber, estimated at 150,000,000 feet, which stood on a plateau high above the existing railroad system. To extend the railroad to reach this timber would have involved the constructing of a series of switchbacks having a total length of 4 miles and costing $32,000; so an incline was built. It was determined that a special lowering engine would be too expensive, considering the fact that this type of engine could be used for no other purpose. A combination engine—one that could be used first for incline purposes and later as a road engine—was selected. This engine has 12 by 14 inch cylinders and a 72-inch boiler, the arrangement permitting the fore end to be converted into a standard road engine with a few changes. The main drum is fitted with a 10-inch shaft, also with a special brake.

The incline is built on a straight line, and has a length of 2,000 feet and a maximum grade of 66½ per cent. Wire rope 1½ inches in diameter is used for a lowering line.

The incline has a capacity of 25 cars per day, the average load amounting to about 7,600 feet. One truck is lowered at a time. An average round trip takes 15 minutes, 4 minutes for lowering the load and 3 minutes for returning the empty to the summit. The other 8 minutes are taken up in hooking and unhooking loads, and in idle time.

The lowering engine cost $6,500; the grading, track laying, etc., $4,700.

TWO-LINE SYSTEM.

The first incline of the two-line type was installed in 1914. The logging manager who devised the scheme was confronted with the problem of removing the timber from 9 square miles of mountainside the lower boundary of which was about 1,200 feet above the main line railroad that ran along the base of the slope. The timber along the bottom of the slope had been logged to this railroad by the ordinary ground yarding method. To open up the timber on the mountainside with a system of railroad spurs of the usual type would have meant the tying up of a large quantity of steel rails, and very long, heavy switching; or, in other words, a heavy investment and high operating cost. It was decided that the topography of this particular area would permit the use of a railroad incline from which lateral spurs could be projected on practical grades, or grades on which a geared locomotive could be operated.

Largely because of the shape of their holdings and the topography of the area, the company had to construct three inclines. These inclines proved very satisfactory. In length they ranged from 4,000 to 6.000 feet. The grades varied. The grades on the first one ranged from 6 to 18 per cent, with the exception of 600 feet of 1½ per cent grade. In the case of one of the others, the maximum grade was 30 per cent. While the aim is to build these inclines on a straight line, or nearly so, it is not always practical to do so. For example, in one case 1,200 feet of the incline was on a 12 degree curve.

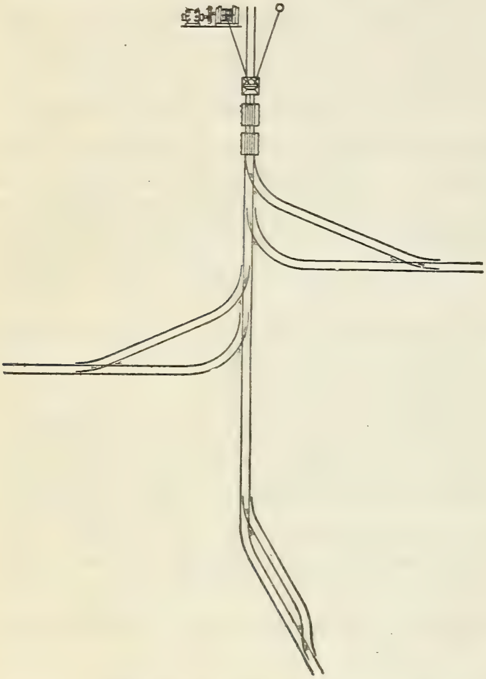

FIG. 70.—Location equipment and tracks, two-line railroad incline.

The incline proper is constructed as in the case of an ordinary railroad spur. There is a siding for the accommodation of empties at the bottom of the incline, also at points on the incline where the lateral spurs, about one-fourth mile apart, connect with it. See figure 70.

The power is furnished by an 11 by 13 inch hoisting engine of the reversible type, which is placed at the top of the slope (fig. 70). This engine, which has a drum capacity of 12,000 feet of 1⅛-inch cable, is mounted on a sled and can be moved from one location to another in the same way as the ordinary ground yarding engine. It has ample power to handle five loaded cars on a 40 per cent grade.

When the system is in operation, the lowering line leads from the engine, which is placed to the left of the incline, then through a block on the lowering car, and thence to a stump or deadman near the engine but on the opposite side of the incline (fig. 70). This doubles the pulling power of the engine.

The loaded cars, where the grade will permit, are attached one to the other in the usual way, with the head load attached direct to the lowering car (fig. 71) by a tag line. Where the grade is steep, the method shown in figure 72 is used. The lowering car has a heavy steel frame and is 16 feet long. A large compound block (fig. 73), triangular in shape and composed of three 3-foot sheaves (fig. 74), is mounted on its deck. The lowering cable passes around the sheaves and over two rollers mounted on brackets on the side of the car. This arrangement gives a clearance of 14 feet between the moving and dead line. This car can be equipped with a gasoline engine, thus making it self-propelling.

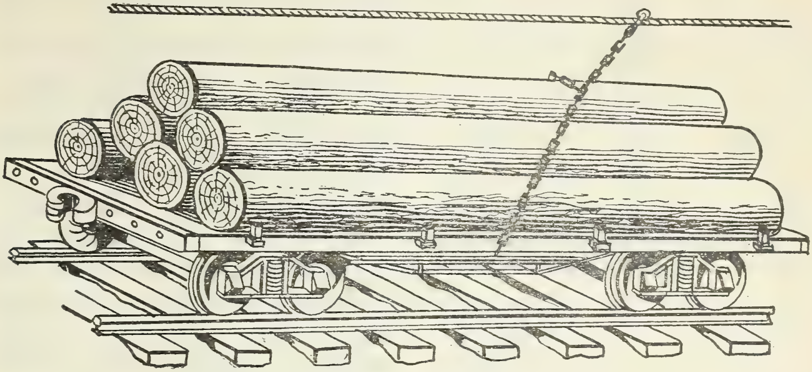

FIG. 71.—Loaded car, two-line railroad incline.

The lowering line never touches the ground. The dead section of it rests on skids laid along one side of the track. These are placed about 20 feet apart and at right angles to the track. The moving section of the line on the other side of the track leads over ordinary sheaves placed about 100 feet apart, the sheaves working in stands that have flared sides. On the inside of the curves the section of the line leads over light twin-road rollers, while on the outside of curves the dead section of the line is held in place by brackets, which auto-

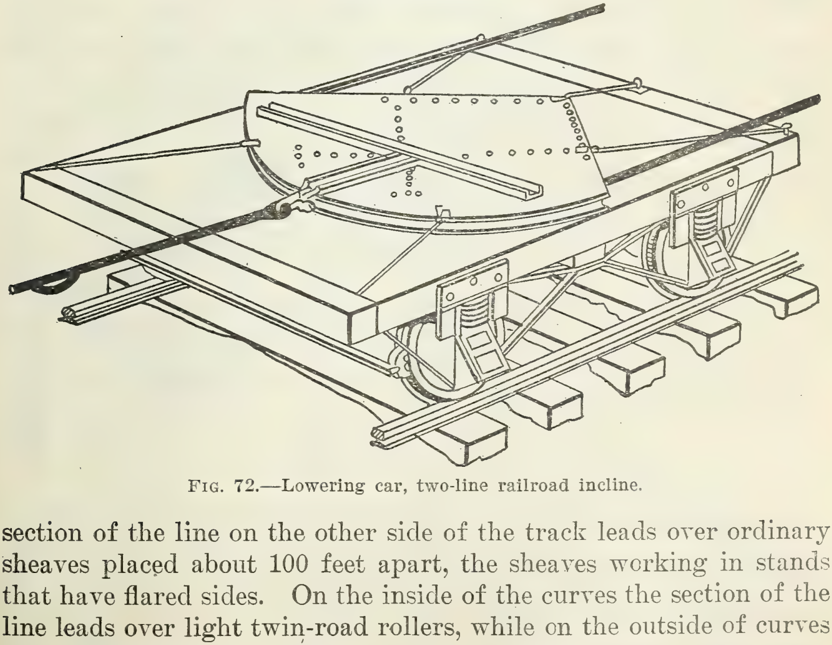

FIG. 72.—Lowering car, two-line railroad incline.

matically release and pick up the line when the lowering car passes that point.

The operation of this system is as follows: The friction on the hoist is released and the weight of the lowering car takes the line to the bottom of the grade, except where the grade is slight. Over such grades the car propels itself by means of its gasoline engine. The lowering car is attached to the empties, and the hoist pulls them up the incline. The lateral spurs being reached, the hoist is stopped, and the empties are dropped on a siding where the locomotive operating on that spur can get them. When the cars are loaded a locomotive takes them to the point where the spur joins the incline. The hoisting car is then lowered, as before, and is used to pull the loaded cars up the grade past the switch and upon the incline ready for their trip down the incline.

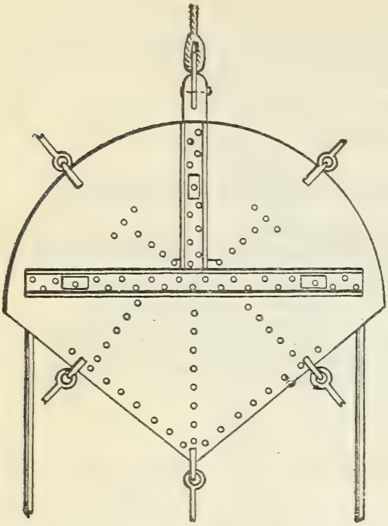

FIG. 73.—Hoisting block, two-line railroad incline.

When operating the 4,000-foot incline, which had a maximum grade of 17 per cent, four cars scaling 32,000 feet were lowered at one time, and it was felt that 40,000 feet would not have constituted an excessive strain on the engine or line. The company, however, made a practice of lowering only three loaded cars and taking back six pairs of empty trucks, since their operation did not demand that more loaded cars be handled at a trip. It never took more than 10 minutes to lower the three loaded cars. During the time this incline was in use no cars were derailed or logs lost. In the case of the 6,000-foot incline, which had a maximum grade of 18 per cent and a 12-degree curve, 26,000,000 feet of timber was lowered without a derailment. On this incline as many as five cars, or 50,000 feet, were lowered at a trip. In the case of the 4,800-foot incline, which was laid on a

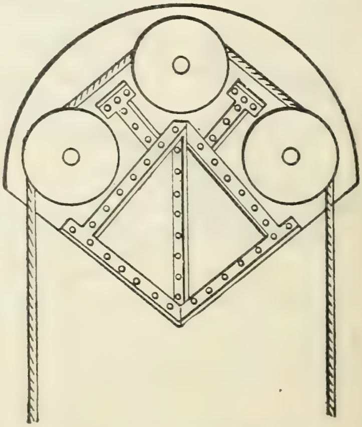

FIG. 74.—Hoisting block (top plate detached), two-line railroad incline.

straight line and had a maximum grade of 30 per cent, two cars were lowered at a trip, 40 cars being lowered in a day.

The operating labor cost per thousand feet varies, of course, with the average amount of timber lowered on the incline per day, the total daily labor cost being to a great extent fixed. The total daily labor cost amounts to about $13 per day, as follows:

	Per day.
1 engineer	$3.50
1 fireman	2.75
1 brakeman	3.50
1 brakeman	3.25
Total	13.00

The life of the lowering line is not known, since no lines have been worn out so far. One line has been used to lower 50,000,000 feet, and it seems that it is not more than one-half worn out.

The fixed investment in the incline equipment proper is approximately as follows:

Lowering engine, together with the sled and small equipment used around the engine	$7,350
Lowering car	1,500
Set of rollers	500
12,000 feet $1\frac{1}{8}$-inch cable	3,500
Miscellaneous equipment	200
Total	13,050

UNLOADING.

Logs as a rule are unloaded, or dumped, into mill ponds, streams, or tidewater. Very small operators sometimes unload logs to, and store small quantities on, the land. The latter is a very unusual practice in the fir region of the Pacific coast.

A number of different methods are used. Only two principles, however, are involved. The logs may be pushed from cars, or in connection with a superelevated track they may be pulled from the cars by gravity.

As a rule, cars are unloaded by means of a rollway, or dump, and an unloading machine. When the logs are dumped into a mill pond or stream, the dump, serving as a part of the railroad track, is generally built along the bank. To dump logs into tidewater it is necessary to extend the track over the water.

The aim of all operators, of course, is to unload logs as cheaply as possible. The cost of this step, however, must be considered in connection with the cost of other steps in the logging operations. In other words, a nice balance should exist between the total cost of unloading logs and the total cost of transporting the logs from the landings to the dump and the cost of booming and sorting. This is particularly true of the balance as it relates to the cost of railroad transportation. It is obvious, therefore, that the method, equipment, and improvements to be used in a given case depend on a number of factors. There is also, of necessity, a relation between the character of the improvements and equipment and the method used.

As a general thing the train crew constitutes all, or the major part, of the help used in unloading. This means that the train is held at the dump until the logs are unloaded, the time depending on the speed of the method. When the railroad haul is short and the output small, a slow method with simple improvements and equipment is the cheapest, all things being taken into consideration. If the logging train is crowded because of a long haul or a large output, a more elaborate method may be necessary than may seem to be justified by the unloading operation in itself.

If the water is deep and has a current, the dump may have only one track and be comparatively short, making it possible to use a stationary unloading rig satisfactorily, since the logs will float away as soon as they are dumped. While still, deep water does not greatly increase the difficulty of unloading logs, it does constitute a drawback. If logs are dumped rapidly into still, deep water, the disturbance caused by their falling will not be sufficient to keep the logs from piling up, necessitating in some cases the employment of an extra man. Shallow water is a serious drawback. Where the unloaded logs do not float away, more or less breakage results when the logs are thrown on the pile that forms. This is especially true in the case of cedar logs. Then, too, a jam of this kind increases the work of the boom man. Under such conditions, a long dump in connection with a portable unloading machine, or some other device for unloading the logs at different points along the dump, is generally used.

DUMPS.

Where the track is built along the bank of a stream or pond, an inclined dump, over which the logs roll into the water, is generally used. The length, breadth, pitch of skids, strength, etc., depend on the topography and soil formation of the location, the size of logs, the method of unloading, etc. The dump may consist of a framework composed of three parallel sets of stringers, spaced about 8 feet apart, which extend to the water's edge for 60 feet or more. The outer stringer, possibly the middle, projects over the water's edge and is supported on piling or timbers that rest on solid bottom, while the other stringers are supported on round or square uprights placed from 4 to 6 feet apart. Heavy timbers, generally round, are placed on top of and at right angles to the stringers. These timbers are generally laid flush, forming an unbroken floor, with a pitch of from 15 to 25 degrees. The upper ends are placed slightly below the level of the car bunks. As a rule, every third or fourth timber is shod with railroad iron. The total cost of a 60-foot dump of this type, including labor, material, supplies, etc., and excluding the cost of the track, is about $500.

Quite often, as has been indicated, the dump is built on piling over the water. The trestle, for the dump proper, may be long enough to accommodate 20 cars or more. An additional length of trestle is usually necessary to get the cars to deep water. To protect the trestle from falling logs, a row of piling is driven flush with the ends of the ties and far enough from the rail to permit the passage of cars. This row of piling, forming an unbroken wall, is capped with a brow skid, the top of which is a little below the top of the car bunks. It is usually faced with a similar row of piling, the second row being beveled off at the top. If a stationary unloading machine is to be used, the dump proper is not more than 70 or 80 feet in length and placed at the most advantageous point, taking into consideration the depth of the water and the arrangement for sorting and rafting.

The cost of dumps of this character varies greatly, for the most part because of the differences in the type, size, and location. The method of unloading also influences it. With these factors known, it is possible to estimate the cost with substantial accuracy. The cost data given under the head of "Railroad transportation" will assist in making an estimate. Further assistance can be secured from cost data published for the use of engineers. The price of piling delivered to a given location, the contract price of driving, and the cost of sawed timber can be learned. If the trestle is built over salt water, the maintenance cost will be much higher than if it is built over fresh water.

PRICE OF PILING.

The price of piling varies from 6 1/2 to 10 cents per linear foot. Douglas fir is usually used, although hemlock is sometimes used in small quantities. The selling prices of winter-cut Douglas fir piling, with 10-inch tops, delivered to the tidewater of Puget Sound, was approximately as follows in April, 1916:

	Cost per linear foot.
25 to 40 foot piles	$0.080
45 to 50 foot piles	.085
55 foot piles	.090

The specifications for piling may include the following: That piles 20 to 30 feet in length shall have 9-inch tops; that piling 30 feet or over in length shall have 10-inch tops; that the piling shall not be less than 14 inches nor more than 22 inches in diameter at a point 6 inches from the butt end; that there shall not be more than $1\frac{1}{4}$

inches of the sapwood at the top of the piles; and that a line drawn from center to center shall lie within the pile.

COST OF DRIVING PILING.

Pile driving is usually done by contract. Contract prices vary, for the most part with the size of the job, the distance the equipment has to be moved, the character of the structure, the length of the piling, and the character of the formation the piles are to be driven in. When the piling is driven in relatively deep water, the contract price for driving amounts to about $1.50 per pile.

Contractors figure that the cost of driving amounts to about $1 per pile, and that their profit should amount to about $0.50 per pile. The following shows the approximate daily cost per pile-driving crew to the contractor.

	Cost per day.
Labor:	
Foreman	$5.00
Engineer	4.00
Loftman	3.00
Boom man	3.50
Roustabout	3.00
Total	18.50
Pile driver:	
Fuel and other supplies, maintenance and depreciation of equipment, interest on investment, etc	10.00
Grand total	28.50

A crew will drive from 25 to 30 piles in a day.

LIFE OF PILING.

The average life of piling in salt water under ordinary conditions is from 3 to 4 years, the maximum 5 years. Where the water is less salty, the life of piling is longer. For example, at or near Bellingham, in the waters of Bellingham Bay, it is about 7 years. This is due to the fact that the Nooksack River discharges a large volume of fresh water into this bay, hindering the rapid growth of the animal life that is so injurious to piling. There are other cases where the life of piling driven in salt water is longer than this.

COST OF PILE-BENT TRESTLES.

The cost of trestles is discussed in works dealing with the economics of engineering construction. The cost of five-pile-bent trestles of standard construction when built over the tidewaters of the region, the piles averaging about 40 feet in length, amounts to about $6 per running foot. This is the complete cost exclusive of the rails.

The cost of a bent with 15-foot centers is approximately as follows:

5 piles, driven and capped (material and labor), at $10 per pile	$50.00
2,200 feet of timbers in place, including labor and material (timber, iron, spikes, bolts), at $19 per thousand feet	41.80
Total cost per bent	91.80

The following indicates the character, size, and amount of material used:

5 piles, averaging 40 feet in length.
1 cap, 12 by 14 inches by 14 feet.
2 sway braces, 3 by 10 inches by 14 feet.
6 stringers, 8 by 16 inches by 15 feet.
12 ties, 6 by 8 inches by 12 feet.
3 ties, 6 by 8 inches by 14 feet.
2 guard rails, 6 by 8 inches by 15 feet.
2 planks, 2 by 12 inches by 15 feet.
30 boat spikes.
6 bolts, ¾ by 11 inches.
4 bolts, ¾ by 19 inches.
4 bolts, ¾ by 29 inches.
5 drift bolts, ¾ by 24 inches.
4 drift bolts, ¾ by 32 inches.

METHODS.

SUPERELEVATED RAIL.

A number of operators unload their logs very satisfactorily by means of a superelevated track. The railroad track is laid parallel with the dump and so that the top of a car in passing will be about 6 inches away from it. The outer rail is elevated from 12 to 16 inches, thus throwing the side of the car next the dump at a lower level. Most of the logs will roll from the car into the water when the car stakes are removed, the dogs on the car bunks lowered, or the binder chains loosened. The remainder of the logs are rolled off the car by means of logging jacks, levers, or makeshift gill pokes. This is one of the simplest methods of unloading, being extensively used, especially where the output is small and the logs are dumped into a mill pond. It may be used with all types of dumps.

LOGGING JACKS.

The depth of the water and the height of the track above the water may make it necessary to dump the logs at different points along the dump rather than at one point. Under such conditions, if the output is small or if the train crew is not crowded, it may be economical for the train crew to unload the logs with logging jacks. To facilitate unloading with this method, the track is slightly superelevated, which results in some of the logs rolling from the cars when the car stakes are cut or tripped or the binder chains loosened. The remainder are pushed from the cars with logging jacks.

At one camp where unloading is done with this method, a crew of three men—two brakemen and a dump man—unload eight cars, averaging about 7,500 feet to the car, in about 30 minutes. The dumping is seldom accomplished in less than 20 minutes, and it sometimes takes an hour. The cars are equipped with patent stakes. Considerable time is lost because the brow skid is too high. The logs average about 2,000 feet in volume.

TILTING DUMP.

The tilting dump is used by a few operators. The dump is usually built in paired sections, each 40 feet in length, with 30 feet of stationary track between. This arrangement permits logs of any length to be dumped. Two cars loaded with 40 foot logs can be dumped at the same time. When the logs are longer, one load is dumped at a time, a truck being "spotted" on each of the two sections, which are tripped simultaneously.

Piles capped with timbers form the foundation. The roller timber—a stick 42 feet long and 20 inches square—and two stringers, supporting a floor of ties and the latch stringers, form the platform of the dump. The five latch timbers on each section of the dump extend about 2 feet beyond the ties on the land side and are fastened down by means of iron latches. This arrangement holds the sections level when the loads are run on. The center latch timber, which is known as the trip timber, is longer and larger than the others, being 36 feet long, 9 by 18 inches at one end, and tapering to 9 by 12 inches at the other, or latch, end. The roller timber works on heavy cast-iron chains which rest on the sills.

The operation is simple. When the cars are spotted, the chains taken down, and the latches knocked off, gravity causes the dump to revolve 15 degrees on its axis, rolling the logs from the cars. This action is due to the fact that the center of the track is placed about 3 inches from the center of the roller timber on the water side. The dump is brought back into position by the workmen walking out on the trip timber. Loads heavy on the land side will not trip the dump. Under such conditions, the tilting action is started by lifting up on the trip timber. Slabs will not always roll off at the inclination provided, making it sometimes necessary to use a gin pole and parbuckle line. The design of the dump is shown in a general way in figures 75 and 76.

At one camp which uses this method, three men—two brakemen and the locomotive fireman—dump the logs at the rate of one car per 2½ minutes, a large part of this time being consumed in taking down and

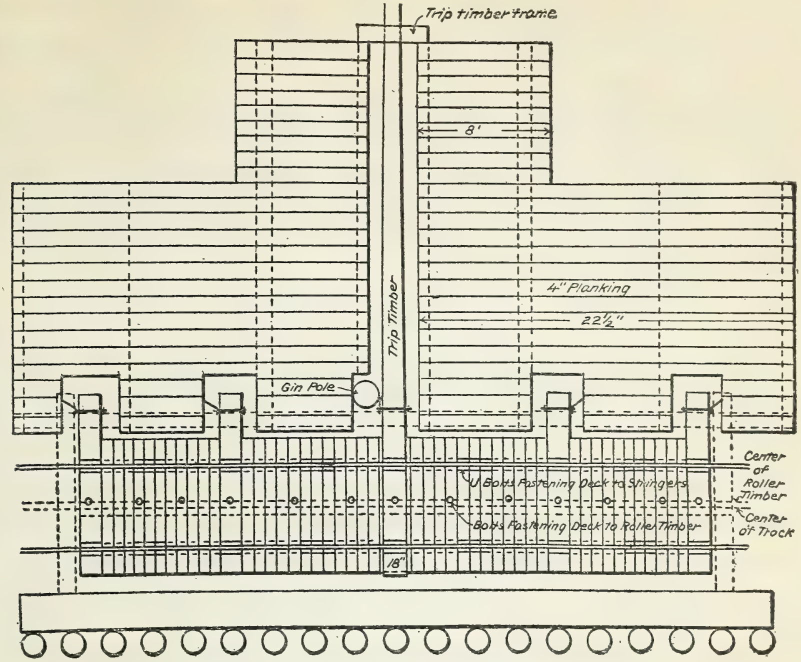

FIG. 75.—Floor plan of a tilting log dump.

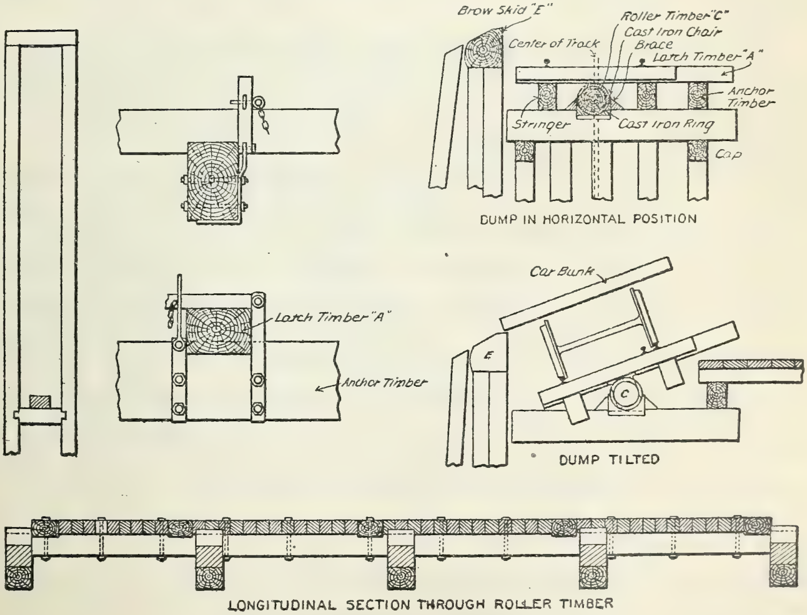

FIG. 76.—Details of a tilting log dump.

putting up the binder chains. If the trucks were equipped with patent stakes, the time consumed in unloading would be considerably less.

The cost of dumps like that described above varies with different locations and different soil formations. Under ordinary conditions, the cost, not including the approaches, should range from $2,000 to $2,500. The maintenance of one of these dumps for 7 years cost about $300 per year. During this time the dump was practically rebuilt through maintenance.

GIN POLE.

A number of operators unload logs under conditions that render a gin pole and parbuckle line a practical method. The gin pole, which is about 35 feet in height, is erected along the track on the land side, with the ⅞-inch parbuckle line leading through a sheave block at the top of the pole. In unloading, one end of the line is passed under the load to the opposite side of the car and fastened to the brow skid. When the line is tightened by power applied at the other end, the load is raised from the car bunks and pushed from the car. With this method a mast, or pole, to which a cross arm is braced about 20 feet from the track, is used in most cases instead of a gin pole, the parbuckle line leading through a sheave block at each end of the cross arm. The cross arm extends over the track about 8 feet.

The logs are dumped at one point, which, as has been suggested, is not practical under all conditions. Some operators eliminate this objectionable feature by using a number of gin poles erected car lengths apart along the dump.

The power as a rule is furnished by the locomotive, the hand work being done by the train crew. When a number of gin poles are used, the locomotive is the only practical source of power. In some cases, where it is desirable to unload as quickly as possible, the power is supplied by an ordinary logging engine, generally an old one, necessitating the employment of an unloading engineer in addition to the regular train crew. If the logs are unloaded in a pond near the mill, the power may be furnished by a hoist, the steam being furnished by the mill. In one case a 6¼ by 10-inch single-drum hoist is used, the machine being operated by the locomotive fireman. The engineer spots the cars and the brakemen adjust the parbuckle line. When the dump is located near a power plant, an electrically driven hoist may furnish the power. In one case, a 30-horsepower Westinghouse motor, connected with the drum shaft by a double-reduction gear, is used. The two drums are operated on this shaft by ordinary logging-engine frictions. One drum carries the parbuckle line; the other, which can be operated independently, is used for miscellaneous purposes.

This method is slower when the locomotive is used to spot the cars and to furnish the power in unloading than when the power used to operate the parbuckle line is furnished by a separate engine. With the former source of power it takes from 2 to 3 minutes to unload a car of logs; with the latter, from 1 to 1½ minutes.

GILL POKE.

(1) One of the simple gill-poke devices is as follows: The track on the entire length of the dump is slightly superelevated. Parallel to the track on the land side, and about 5 feet above the level of the track, there is a timber with notches cut at proper distances. The arm of the poke is a stick of wood 4 by 3½ inches by 6 or 8 feet, which is shod with a sharp steel prong at the pointed end and has a collar at the blunt end. In operation the pointed end of the poke is placed against the logs and the heel is inserted in one of the notches in the timber, the positions of the poke being such that it will push the logs from the car when the car is put in motion. Thirty-two cars, containing 150,000 feet, have been unloaded with this method in 20 minutes.

(2) Another gill-poke device is shown in figure 77*a*, *b*. The top of the center pile, to which the arms, or sweeps, are hung, is about 12 feet above the level of the track. The arms are about 30 feet in length, the center pile being so located as to enable them to reach across the track when the machine is in operation. The four piles which surround the center piling are bound together with a 1-inch wire cable and serve no other puropse than to brace the center pile. In the case shown in the figure, the distance from the arms to the ground is about 12 feet. If the distance is greater than this, additional piling is necessary. There are 2 or 3 inches of play between the center piling and the points where the arms are joined together, making it possible to raise or lower an arm preparatory to engaging a load of logs. A heavy plate of iron is bent half around the center pile at the point where the arms press when in operation. With the chock blocks tripped, the train crew can unload several cars of logs per minute. Under ordinary conditions the total cost of this device installed ranges from $600 to $800.

(3) Two arms are sometimes used. In one case they are 17 feet long and made of channel and angle iron. They are 18 inches wide except at the ends, where they are made 36 inches wide to give a broad surface to repel the logs. They are bolted opposite to each other on a 24-inch journal, and braced with a turnbuckle. The arms and journal are set on a shaft 11 feet long and 10 inches in diameter, cut down to 8 inches where the journal is fastened to admit

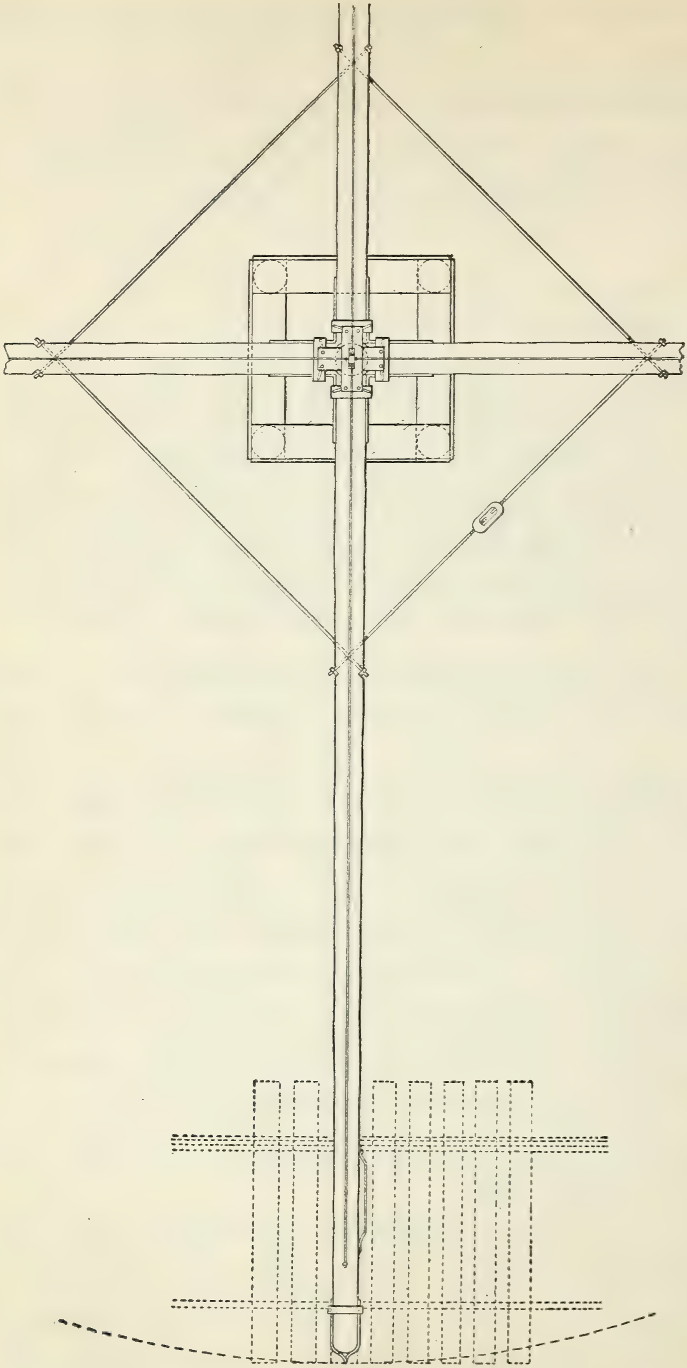

FIG. 77*a*.—An improved device for unloading logs. (Top plan view.)

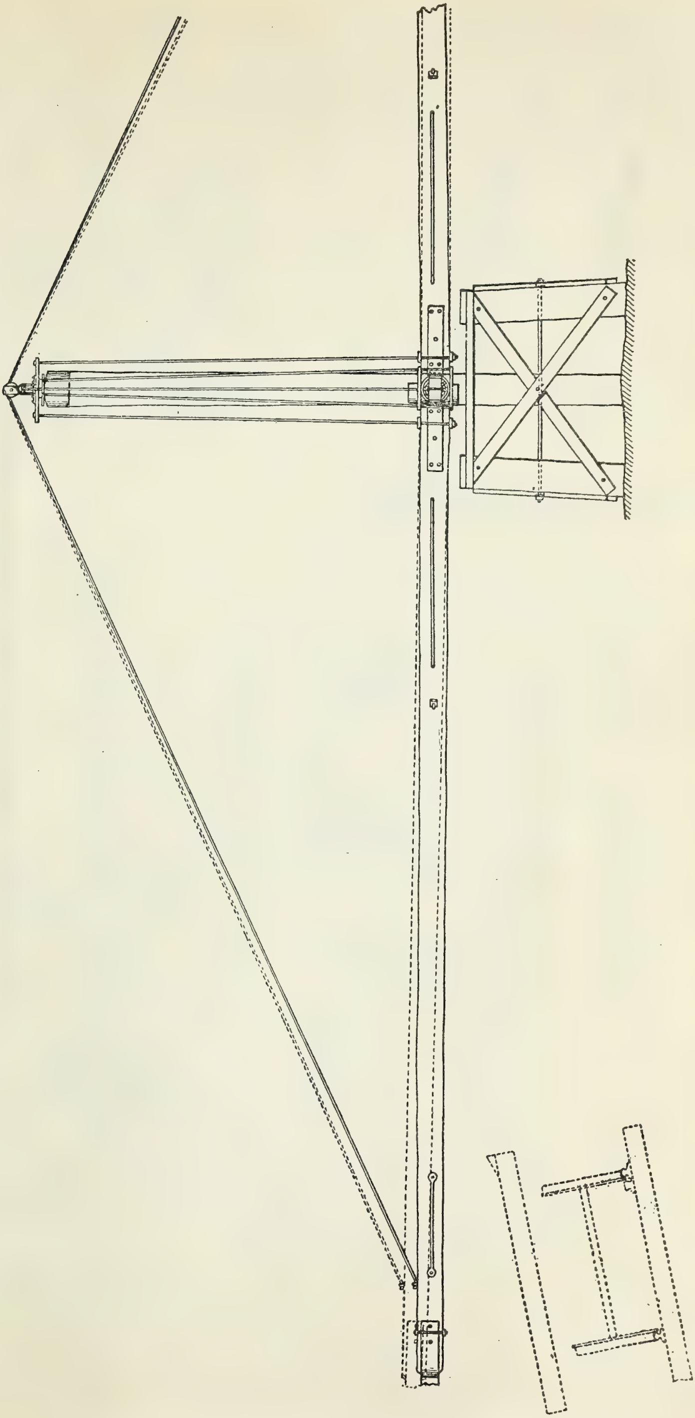

FIG. 77b.—An improved device for unloading logs. (Side view.)

the attachment of a collar with ball bearings. The rest of the shaft, or the part which is 10 inches in diameter, is set in a concrete base, high enough to allow the arms to clear the bunks, and far enough from the track to permit either arm when at right angles with the track to reach 1 foot beyond the outer rail. The concrete base is 9 feet square at the bottom and 6 feet square at the top. The repelling ends of both arms are fitted with steel castings. These steel castings have sharp cutting edges, one of which engages a load of logs as the train moves toward the unloading device, penetrating the nearest log, thereby doing away with the necessity of attaching the arms to the car by a cable or some other method.

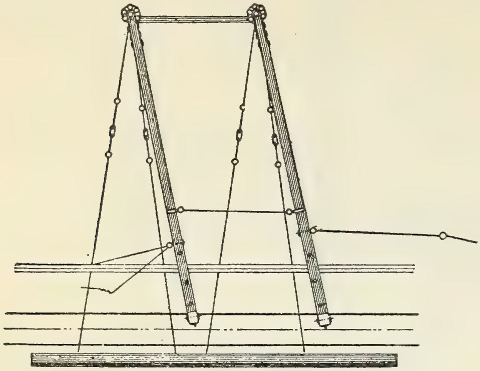

FIG. 78.—Ground plan of two-poke log unloader.

In unloading the train moves toward the unloader slowly, seldom finding it necessary to stop. The average time consumed in unloading 15 cars of logs, containing approximately 70,000 feet, is about 8 minutes, which includes the coupling of cars, knocking out the blocks, etc.

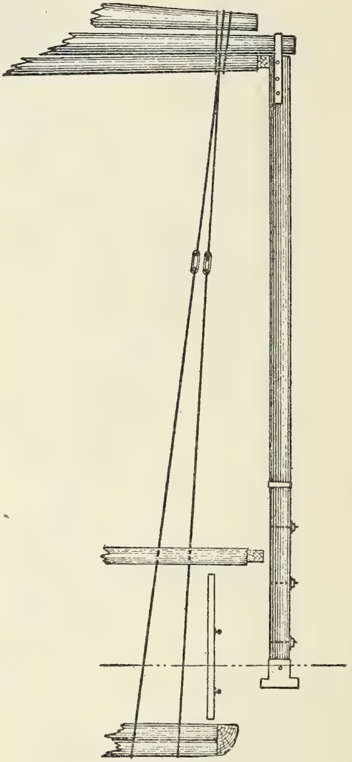

FIG. 79.—Cross section of two-poke log unloader.

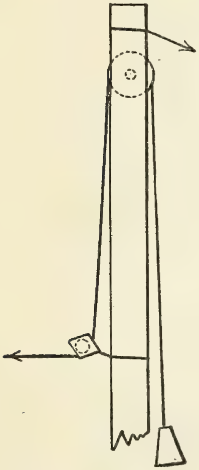

FIG. 80.—Counterweight pile, two-poke log unloader.

The cost of making and installing the machine described above amounted to $1,000; $900 for making and $100 for installing. At the end of three years of use nothing had been spent for repairs. The cost of operation, other than train crew labor, consists of about one gallon of lubricating oil per year.

(4) Figures 78, 79, and 80 show another type of two-poke log unloader. The two arms with this method, however, engage the load at the same time. Gravity is used to pull the arms into position to engage the load of logs. A line fastened to the arms leads through a block hung to a pile, thence through a block at the top of the pile. To the free end of this line a weight is attached. It is thought that the drawings are self-explanatory, making comments dealing with the construction and operation of the device unnecessary. The machine is said to unload one car of logs per minute under favorable conditions. In one case, with this device, cars were unloaded at the rate of one car every 3 minutes.

The total cost of making and installing this device depends on the location, ranging from $700 to $1,000. The bill of material is approximately as follows:

BILL OF MATERIAL.

Piles:
    83 50-foot piles.
    1 75-foot pile.
Caps:
    66 linear feet 12 by 14 inch timbers.
    24 linear feet 12 by 12 inch timbers.
    2 pieces 6 by 12 inch by 14 feet.
    1 60-foot log, 2 feet in diameter.
    2 ¾ inch by 30 inch bolts.
    3 ¾ inch by 16 inch bolts.
    10 ¾ inch by 16 inch bolts.
    10 ¾ inch by 5/16 by 3 inch washers.
    30 ¾ inch by 24 inch drift bolts.
    240 square feet ¼-inch sheet iron.
    60 6-inch boat spikes.
Booms:
    2 50-foot logs, 1 foot 6 inches in diameter.
    2 unloader points.
    2 ¼ inch by 6 inch by 12 feet sheet iron.
    28 ¾ inch by 20 inch bolts.
    32 ¾ inch by 5/16 inch by 3 inch washers.
    40 ⅞-inch cable clamps.
    4 1 inch by 9 feet turnbuckles.
    2 1 inch by 20 inch I bolts.
    2 1 inch by 4 inch by 1⅛ inch washers.
    1 14-inch sheave wheel.
    1 1 inch by 16 inch bolt.
    1 ¼ inch by 3 inch by 18 inch sheet iron.
    2 1 inch by 4 inch by 1⅛ inch washers.
    2 10-inch single sheave blocks.
    1 20-foot 1¾-inch log chain.
    2 ¼ inch by 1 foot 6 inch diameter sleeves.
    2 ¼ inch by 4 inch diameter rings.

PORTABLE ENGINE.

Where it is not practicable to dump all the logs at one spot, or where it is desirable to dump them at different points, it may be necessary to use a self-propelling unloader, which runs on an independent track along the main track. Moving from car to car, the machine unloads each car in rapid succession. To unload, the line is passed under the load and made fast to the brow skid. The friction drum is thrown in, tightening the line. This action raises the load free from the bunks, and at the same time pushes it off. This machine can also be used as a general utility car for building bridges, picking up stray logs along the track, building track, etc.

There are two types of portable unloaders. One has a stationary boom, a single drum, and reversible engines. The other has a live boom, which makes two drums necessary. A live boom increases the use of the machinery, since it makes it possible to reach out over the pond to break jams or pick up loads from barges. The engines of this type of unloader are not reversible, they are made to back by a change of gears. The machines have a capacity of about 20 tons and will run up an 8 per cent grade. The stationary boom machine is shown in figure 81.

The selling prices of these unloaders f. o. b. the factory are: Stationary-boom type, $2,500; live-boom type, $3,500. Since the use of this machine necessitates a second track, the cost of constructing a dump is greater when it is to be used with a portable log unloader than when some other method is to be used.

The work of unloading is generally done by the train crew, with the assistance of an unloading engineer. In some cases when the logs are delivered at the dump by a common carrier railway company the unloading is done by the booming and sorting crew. The work proceeds about as rapidly with this method as any other.

WATER TRANSPORTATION.

Water has been used to transport logs in every important lumbering region of the United States. It is still used extensively in the eastern part. In other regions it has to a great extent been superseded by railroads, because of the exhaustion of the timber supply near drivable streams, the extensive logging of nonfloatable species, and the increased value of stumpage.

Water transport never gained the foothold on the Pacific coast that it did in other lumbering regions, and it is now of minor importance, except where the logs are brought to the shores of the Columbia River, Puget Sound, Grays Harbor, Willapa Harbor, and other points on the Pacific Ocean, and then rafted and towed to the mills. The superiority of railroads over river driving was realized by logging operators before the timber resources of the region under discussion were to any extent opened up. Furthermore, this region is not traversed by numerous streams suitable for the driving of the large timber that is characteristic of the region. Of course, logs are frequently dumped into relatively large rivers near their mouths and allowed to float singly for short distances to the sorting and rafting works.

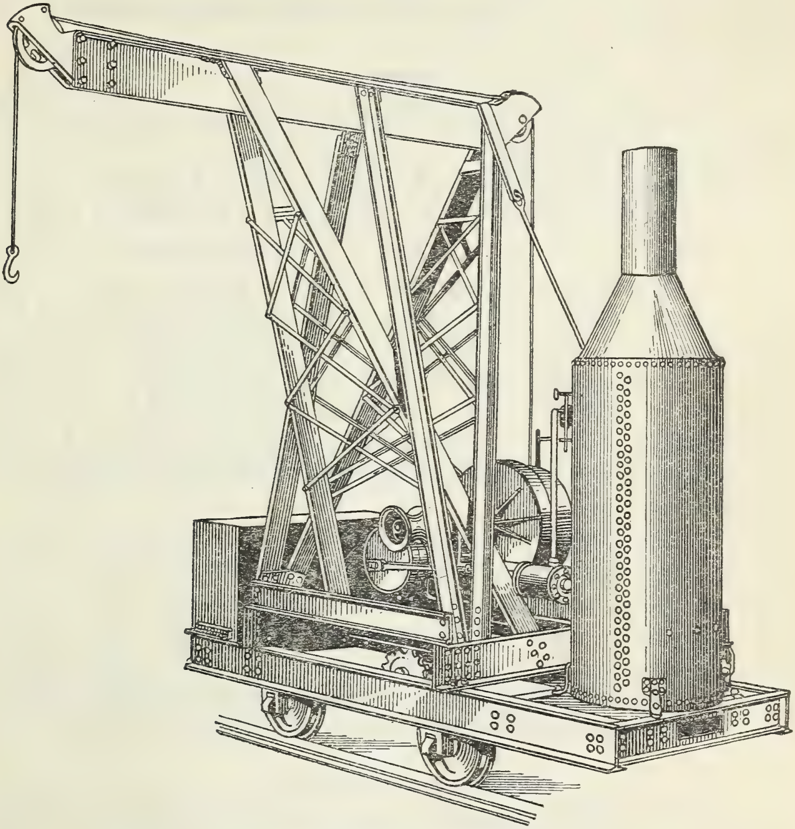

FIG. 81.—Stationary-boom unloader.

Flumes and sluices are used in different regions of the United States to transport sawlogs, shingle bolts, crossties, cordwood, pulpwood, mine timbers, and the like from the forest to the mills, drivable streams, or railroads. In the Douglas fir region, however, log flumes are not used. To the knowledge of the writer only one logging operator uses one. For this reason a discussion of log fluming has no place in this publication. Fluming is dealt with in Bulletin 87 of the Department of Agriculture, under the title of "Flumes and fluming."

DRIVING.

The driving of logs on rough water and small streams is practiced only to a limited extent in the Douglas fir region, and, excepting a few cases, only in the Grays Harbor and Willapa Harbor sections. Most of the timber so transported is driven on improved streams by separate driving companies at fixed rates per thousand feet, the driving of timber on unimproved streams being a very primitive method, which is resorted to only to a limited extent. Very little National Forest timber has been, or will be, driven in the form of sawlogs.

RATES.

The following are the driving rates on the Humptulips and Wishkah Rivers in Washington:

On the Humptulips River all logs 40 feet and under in length vary from $0.30 to $0.60 per thousand feet. The airline distance ranges from 14 to 34 miles. On logs 42 to 60 feet in length the rate is from 45 to 75 cents, and on logs over 60 feet in length the rate is from 65 to 95 cents. The cost of breaking out landings is borne by the logging operators. On the Wishkah River the rate for logs 40 feet and under in length ranges from 60 to 75 cents per thousand feet. The distance is from 15 to 28 miles. On logs 42 to 60 feet in length the rate is from 75 to 90 cents, and on logs over 60 feet in length from 95 cents to $1.10 per 1,000 feet. A number of splash dams have been established on these rivers.

The driving companies assume charge of all the logs delivered afloat in the ponds of the dams or in the bed of the rivers below the dams, but, as has been pointed out, not in the landings. They operate their dams, and sluice, drive, and sack all logs in accordance with the driving act in the State law. The companies reserve the right to select the time when the streams shall be sacked, with the understanding that sacking will continue until all logs are delivered in the booms.

SORTING AND RAFTING.

It is the common practice of many logging operators to dump their logs into large streams or tidewater, so that the logs may be sorted, rafted, and towed to the mills. Two forms of rafts are employed. In a few cases in the Puget Sound region, the log output is dumped into rivers and made up into round, temporary rafts, the contents of such rafts being made into permanent rafts when they are delivered to tidewater. Practically all rafted logs, however, are made into permanent rafts at the unloading point.

SORTING.

In the early history of lumbering in the region, logs were bought and sold on the basis of "camp run;" that is, a logging operator sold all the logs produced by his camp at an average price per thousand feet regardless of the percentage of the several species or the size and quality of the logs. At that time, when the selling price of the logs was low, or when the price of stumpage was low and the cost of logging considerably less than it is now, this method seems to have been satisfactory. As the price of logs advanced, the practice of selling on the basis of species and grades sprang up. Now the bulk of the log output of independent loggers is sold on this basis. Furthermore, independent loggers are giving considerable attention to the matter of further standardizing existing grades, also the question of the feasibility of increasing the number of grades. That there should be satisfactory standard grades for logs and that the grades should be as numerous as is practical can not be questioned. The loggers of British Columbia seem to have gone farther in the way of defining the log grades than those of the Columbia River and Puget Sound regions, and it would seem that the loggers could go still farther in any one of these three regions.

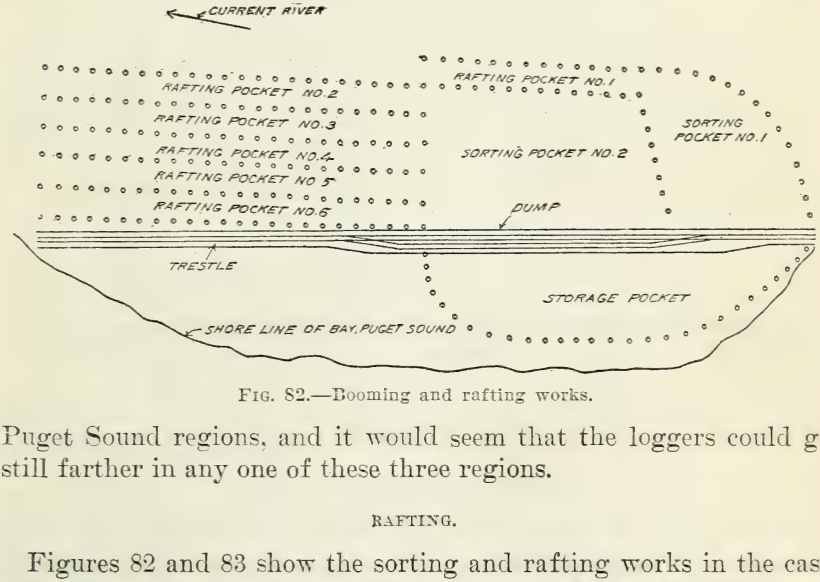

FIG. 82.—Booming and rafting works.

RAFTING.

Figures 82 and 83 show the sorting and rafting works in the case of two operations in the Puget Sound region. All works of this kind in this region are much the same, any differences, for the most part, being the result of differences in location and capacity. The main, or sorting, pocket, into which the logs are dumped, is a large area surrounded by logs chained end to end and held in place by piling. The rafting pockets, lanes leading off from the sorting pocket, are about 75 feet wide and from 800 to 1,000 feet long, and consist of parallel rows of piling, the piles being driven from 15 to 60 feet apart. Dolphins, consisting of three, four, or five piles driven in a cluster and bound together with a cable, are located at several points for mooring posts for tug boats and completed rafts. In addition to these improvements certain equipment, such as boom sticks, boom chains, peavies, axes, and pike poles, are required.

After the logs have been unloaded into the boom different species and grades are poled to different parts of the sorting pocket. This operation is not a distinct operation in the sense that all logs are sorted before rafting begins, since sorting and rafting may be considered as occurring at the same time. The rafters then string boom sticks across the far end and along both sides of the rafting pockets. Logs of approximately equal lengths are then poled or floated down the rafting pockets and stowed parallel to each other in the far end. Each row is known as a "tier," and two tiers usually constitute a "section." Manifestly all the logs in a section can not at all times run parallel with the outside boom sticks, some of them being placed at right angles to these sticks. The main consideration is to place the logs so that the raft will be as compact as possible. As soon as a section is filled, a boom stick, called a swifter, is placed across the end at right angles to the outside boom sticks in order to keep the logs closely packed. New sections are then made up in the same manner, 10 to 14 sections constituting a raft. This applies to tidewater booms, where the work can be carried on only during a favorable tide. On large streams the procedure is practically the same.

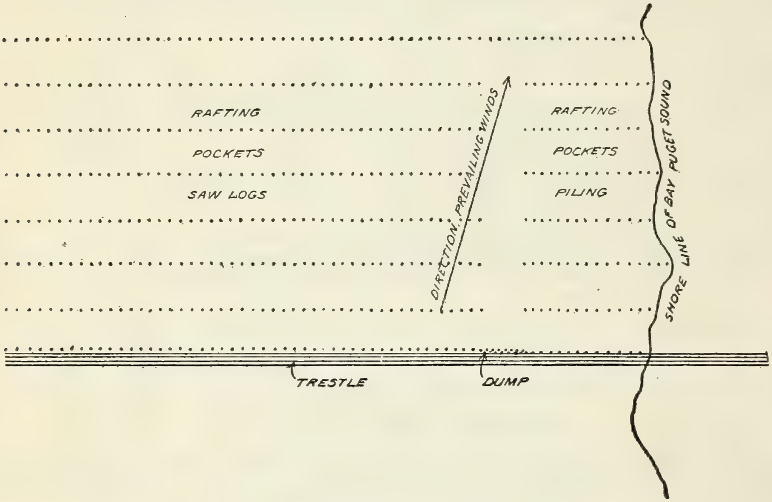

FIG. 83.—Booming and rafting works.

The cost of a rafting and sorting works depends for the most part on the capacity, the method of sorting the logs, and the spacing of the piles. In the case of the works shown in figure 82, the cost amounted to $1,000. The total number of piles driven was 250. The piling, which averaged about 32 feet in length, cost 6½ cents per linear foot or $2 per pile. The cost of driving was $2 per pile.

In the case of the works shown in figure 83, the cost was about $1,500, the piling costing $4 per pile in place.

The maintenance of sorting and rafting works depends for the most part on the life of the piling. In the case of the $1,000-works, the piling has a life of about 4 years; in the other case, 8 years. This means that the annual maintenance cost amounts to $250 and $188, respectively.

Outside boom sticks are from 75 to 82 feet in length; swifter sticks, from 66 to 70 feet. They are straight, sound, have a little taper, average about 16 inches at the small end, and have holes bored at each end for the insertion of boom chains. The average cost of an outside boom stick, with holes bored, is about $11; the average cost of swifter sticks similarly prepared, $7.50. Boom chains for outside sticks, made of 1-inch iron and weighing 80 pounds, cost about $4.50 per chain. A swifter chain, made of a little lighter iron, costs about $3.50. These chains are from 6 to 8 feet long and have a ring at one end, a toggle at the other. Standard light driving peavies are used in rafting. They cost about $2 each. The pike poles, which average about 24 feet in length, cost about $5 each. The total cost of boom sticks and chains for a complete raft is as follows:

31 outside boom sticks at $10	$310.00
10 swifter sticks at $7.50	75.00
31 boom chains at $4.50	139.50
10 swifter chains at $3.50	35.00
Boring holes for 41 sticks	41.00
Total	$600.00

The life of boom sticks averages from two to three years. Boom chains have about the same life. Of course, in fresh water this equipment lasts much longer.

Sorting and rafting in the Columbia River and Puget Sound regions are ordinarily done by the logging operators with day labor. In a few cases it is done by separate companies at fixed rates per thousand feet. The rates in one case in the Puget Sound region are 35 cents per thousand feet for western red cedar and 25 cents per thousand feet for the other species. These rates include the unloading as well as the sorting and rafting of the logs. The logging companies furnish their own boom sticks.

In the Grays Harbor region logs driven or dumped into tidewater or the Chehalis River are generally rafted and sorted by separate companies at fixed rates per thousand feet. The sorting and rafting company operating at the mouth of the Humptulips River charges the following rates: For catching, sorting, rafting and delivering at the boom, 50 cents per thousand feet on logs or other timber products under 40 feet in length; 15 cents per thousand feet extra for logs 42 to 60 feet in length; 35 cents per thousand feet extra for logs over 60 feet in length. The company reserves the right to base its charges on the mill scale or its own scale at the boom. Upon receipt of logs in the boom the company proceeds to raft them without unreasonable delay. As soon as a raft is ready for delivery and in absence of instructions from the owners as to its disposition, the company reserves the right, after giving five days' notice, to store the logs and to charge 10 cents per thousand feet for each thirty days or any fraction thereof. When logs are stored an additional charge of 25 cents per thousand feet is made for rafting and delivering the logs to the storage grounds. The company operating at the mouth of the Wishkah River charges the following rates: For catching, sorting, and delivering at its boom in suitable sticks furnished by the owners of the logs, 40 cents per thousand feet for all logs and other timber products under 40 feet in length; 15 cents per thousand feet extra for logs 42 to 60 feet in length; 35 cents per thousand feet extra for logs over 60 feet in length. The storage charge is 25 cents per thousand feet for the first month and 10 cents per thousand feet for each additional month. This charge includes the cost of delivering the logs to storage.

Logging operators frequently contract the sorting and rafting. In one case the operator paid the contractor $1 per car for unloading, sorting, and rafting. This is at the rate of about 13 cents per thousand feet. The contractor only furnishes the operating labor, the dump and booming grounds being kept in repair by the logging operator.

The labor cost of sorting and rafting, where it is done by logging operators, ranges from 6 to 17 cents per thousand feet of output. In the case of 18 operations in the Puget Sound region the following range of labor costs was found:

Number of camps.	Labor cost per thousand feet.
	Cents.
3	6 to 8
7	9 to 10
6	13 to 15
2	16 to 17

In the case of 8 operations in the Columbia River region the following range of labor costs was found:

Number of camps.	Labor cost per thousand feet.
	Cents.
6	8 to 10
2	12 to 14

The variation in the labor cost of sorting and rafting is due to differences in the conditions under which the men work, or the average volume of timber sorted and rafted per man. In the case of a tidewater operation, a crew of seven men, working under favorable conditions, sorted and rafted 500,000 feet per day. The crew and wages were as follows:

Foreman	$125.00 per month.
Boom man	3.50 per day.
4 rafters (each)	3.00 per day.

Under adverse conditions when the wind is blowing in the wrong direction this crew will do less. In running water where the current carries the logs down the rafting pockets, a crew of four men may average as much as 500,000 feet per day. As a rule, each member of the crew, including the foreman, will average from 40,000 to 60,000 feet per day.

TOWING.

In the Columbia River and Puget Sound regions the cost of towing the logs from the booms to the mills, as a rule, is borne by the manufacturers, while in the Grays Harbor and Willapa Bay regions this cost, as a rule, is borne by the independent loggers. The operation is performed by separate companies at fixed rates per thousand feet. The rates charged in the Columbia River, Puget Sound, and Grays Harbor regions are as follows:

TABLE 33.—*Rates for towing logs on Puget Sound, 1915.*

	Anacortes.	Apple Tree Cove.	Ballard.	Blanchard.	Brown's Bay.	Port Susan.	Priest Point.	Mukilteo and Everett.	Seattle.	Blakely.	Tacoma.	Seabeck, Tarboo, and Brinnon.	Shelton.	Utsalady.	Bellingham.	Cherry Point.	Blaine.	Gamble.	Hadlock.	Union City and Potlatch.	Henderson Bay and Olympia.
Apple Tree Cove	$0.50	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Ballard	.50	$0.25	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Blanchard	.25	.60	$0.60	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Port Susan	.45	......	.35	$0.50	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Priest Point	.45	......	.25	.50	$0.20	$0.25	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Everett	.45	.30	.25	.50	.20	.25	$0.15	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Seattle	.50	.25	.15	.60	.20	.35	.30	$0.25	......	......	......	......	......	......	......	......	......	......	......	......	......
Blakely	.50	.25	.20	.55	.20	.35	.30	.30	$0.15	......	......	......	......	......	......	......	......	......	......	......	......
Tacoma	.60	.35	.30	.70	.35	.45	.40	.40	.25	$0.25	......	......	......	......	......	......	......	......	......	......	......
Seabeck, Brinnon, and Tarboo	.60	......	.40	.65	......	......	.40	.40	.40	.40	$0.50	......	......	......	......	......	......	......	......	......	......
Shelton	.60	.40	.40	.70	......	.50	.45	.45	.35	.30	.25	$0.70	......	......	......	......	......	......	......	......	......
Utsalady	.30	.35	.35	.40	......	.35	.30	.30	.40	.40	.45	.45	$0.55	......	......	......	......	......	......	......	......
Bellingham	.25	.60	.60	.20	.50	.50	.50	.50	.60	.60	.65	.65	.70	$0.40	......	$0.25	......	......	......	......	......
Blaine	.45	.70	.70	.45	.70	.70	.70	.70	.75	.75	.85	.75	.75	.55	$0.40	.25	......	......	......	......	......
Gamble	.50	.30	.35	.55	.25	.40	.30	.30	.35	.35	.45	.25	.45	.40	.55	......	$0.70	......	......	......	......
Hadlock	.60	.35	.40	.60	.40	.45	.40	.40	.40	.40	.50	.40	.45	.40	.65	......	.75	$0.25	......	......	......
Potlatch	.65	.45	.45	.70	......	.50	.45	.45	.45	.45	.60	.25	.80	.50	.70	......	.85	.30	$0.45	......	......
Olympia	.65	.40	.40	.70	......	.55	.45	.45	.35	.30	.25	.70	.15	.55	.70	......	.75	.45	.45	$0.75	......
Discovery Bay	[1].50 [2].75	.50	.55	[1].60 [2].75	......	.55	.55	.55	.55	.55	.70	.60	.75	.65	[1].60 [2].75	......	[1].75 [2].85	.45	.35	.60	$0.70
Brown's Bay	.50	......	.20	.50	......	......	......	.20	.20	.20	.35	......	......	......	.50	......	.70	.25	.40	......	......

[1] outside.

[2] Inside.

The cost of towing less than 300,000 feet is the same as for 300,000 feet. One to four sections may be towed at day rates. Demurrage is charged in all cases where the tug boat is delayed through the tow not being ready when the tug boat arrives at the boom. All tows are transported at the owner's risk.

TABLE 34.—*Rates for towing boom sticks on Puget Sound, 1915.*

	Anacortes.	Apple Tree Cove.	Ballard.	Blanchard.	Port Susan.	Priest Point.	Mukilteo and Everett.	Seattle.	Blakely.	Tacoma.	Seabeck, Tarboo, and Brinnon.	Shelton.	Utsalady.	Bellingham.	Cherry Point.	Blaine.	Gamble.	Hadlock.	Union City and Potlatch.	Henderson Bay and Olympia.
Apple Tree Cove	$1.00	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Ballard	1.00	$0.50	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Blanchard	.50	1.00	$1.00	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Port Susan	1.00	.75	.75	$1.00	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Priest Point	1.00	.50	.75	1.00	$0.50	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Everett	1.00	.50	.75	1.00	.50	$0.50	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Seattle	1.00	.50	.50	1.00	.75	.75	$0.50	......	......	......	......	......	......	......	......	......	......	......	......	......
Blakely	1.00	.50	.50	1.00	.75	.75	.75	$0.50	......	......	......	......	......	......	......	......	......	......	......	......
Tacoma	1.25	.75	.75	1.50	1.00	1.00	1.00	.50	$0.50	......	......	......	......	......	......	......	......	......	......	......
Seabeck, Brinnon, and Tarboo	1.25	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	$1.25	......	......	......	......	......	......	......	......	......	......
Shelton	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	.75	$1.25	......	......	......	......	......	......	......	......	......
Utsalady	.75	.75	.75	.75	.75	.50	.50	.75	.75	1.00	1.00	$1.25	......	......	......	......	......	......	......	......
Bellingham	.50	1.25	1.25	.50	1.00	1.00	1.00	1.25	1.25	1.50	1.25	1.50	$0.75	......	$0.50	......	......	......	......	......
Blaine	1.00	1.50	1.50	1.00	1.50	1.50	1.50	1.50	1.50	1.75	1.75	1.75	1.25	$1.00	.50	......	......	......	......	......
Gamble	1.25	.75	.75	1.50	.75	.75	.75	.75	.75	1.00	.50	1.00	1.00	1.50	......	$1.50	......	......	......	......
Hadlock	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.75	1.00	1.00	.75	......	1.50	$0.75	......	......	......
Potlatch	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.25	.50	1.50	1.00	1.50	......	1.75	.75	$1.00	......	......
Olympia	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	.60	1.25	.50	1.25	1.50	......	1.75	1.00	1.00	$1.50	......
Discovery Bay	1.00	1.00	1.00	1.25	1.00	1.00	1.00	1.00	1.00	1.25	1.00	1.50	1.25	1.25	......	1.75	1.00	.75	1.25	$1.50
Brown's Bay	1.00	......	.50	1.00	.50	.50	.50	.50	.50	1.00	......	1.00	.75	1.00	......	1.50	.75	1.00	1.00	1.00

TABLE 35.—*Rates for towing Douglas fir logs on the Columbia River, 1915.*

Destination.	Upper Cape Horn.	Washougal.	Lake River.	Walkers Island and intermediate points.	Cool Creek, Lower Cape Horn.	Beaver, Westport, Clifton, Eloqueman.	Between Clifton and Tongue Point.	Between Eloqueman and Harrington Point.	Grays Bay and Deep River.	Grays River and Youngs Bay.	Vancouver, Chapman.	Knappa, Stella.	Goble.
Portland	$0.50	$0.50	$0.50	$0.50	$0.55	$0.60	$0.65	$0.65	$0.85	$0.90			
Vancouver			.50	.50	.55	.60	.65	.65	.85	.90			
St. Helens						.45	.50	.50	.70	.75			
Kalama	.60	.55	.25								$0.25		
Rainier	.60	.55	.25								.25		
Prescott	.60	.55	.25								.25		
Westport	.70	.60	.35							.75	.35	$0.20	$0.25

NOTE.—These rates apply to tows of 200.000 feet or more. Tows of less volume are considered as containing 200,000 feet.

The rates for towing cedar, cottonwood, and hemlock on the Columbia River are 10 cents higher than the rates on Douglas fir logs. When cedar, cottonwood, or hemlock tows contain less than 200,000 feet the rates applying to Douglas fir tows are increased as follows:

Less than 50,000 feet, 50 cents extra.
From 50,000 to 100,000 feet, 40 cents extra.
From 100,000 to 150,000 feet, 35 cents extra.
From 150,000 to 200,000 feet, 25 cents extra.

The rate for returning boom sticks from Portland to Grays Harbor and Youngs Bay is 75 cents per stick; from all other points, 50 cents.

On Grays Harbor the towage rates from the booms to the mills at Hoquiam, Aberdeen, and Cosmopolis, including the use of the sticks for rafts, range from 10 to 30 cents per thousand feet. For example, the rate from the boom at the mouth of the Humptulips River to Hoquiam and Aberdeen is 25 cents per thousand feet, and from the same point to Cosmopolis it is 30 cents per thousand feet. From the boom at the mouth of the Wishkah River to the nearest mills the rate is 10 cents per thousand feet, and from the same point to the most distant mills at Hoquiam the rate is 20 cents.

Starting with 1894, several rafts of logs have been towed each year from the Columbia River to southern California. These ocean-going rafts contain from 4,000,000 to 5,000,000 feet of timber, or approximately 10,000 piles. They are built cigar-shaped, generally about 900 feet long and from 50 to 60 feet wide, and draw about 24 feet of water, with 12 feet above the surface.

GENERAL EXPENSES.

Operators find "General expenses" a convenient term to designate costs which are not related to any distinct step in the logging operation, such as supervision of the operation as a whole, office expenses, taxes, selling costs, and miscellaneous items like cruising and fire protection. This classification has not been standardized, and different items of expense are included in it.

General expenses are the most easily overlooked of any in making a timber appraisal. Their inclusion in the calculation is as important, however, as the cost of felling and bucking. The principal general expense charge is general superintendence.

WOODS SUPERVISION.

Many operators include in woods supervision all the supervision of the logging operation from the woods to the raft or mill, also certain general expenses around the camp, such as the pay of the bookkeeper, timekeeper, scaler, logging engineer, night watchman, etc. Other operators prorate such expenses against the major departments of the logging operation. As a rule the salary of the logging superintendent or manager does not appear under this heading. The salaries of the foreman, bookkeeper, timekeeper, etc., are given under the heading "Logging in general."

FIXED CHARGES.

SUPERINTENDENCE.

In the main the industry is not burdened with a superabundance of general salaried help; and low salaries for managers and logging superintendents, considering the character of the work and the capital invested, are the rule.

The cost of superintendence per thousand feet varies from 7 to 20 cents. The cost of superintendence and commissions in the case of twenty camps in the Puget Sound region and ten camps in the Columbia River region is as follows, commissions including the amounts paid by some of the operators to an association or individual for selling the logs:

Number of camps.	Cost per thousand feet.
Puget Sound region:	*Cents.*
7	7 to 10
6	11 to 15
7	16 to 20
Columbia River region:	
4	8 to 10
3	11 to 15
3	16 to 20

The camp of one independent logging operation running four sides is in charge of a foreman who receives $200 per month. The general superintendence of the whole operation, including the disposal of the log output, is in the hands of a manager who receives $5,000 per year. The manager spends from one-fourth to one-third of his time in the woods. The salary of the camp foreman is charged directly to the cost of running the camp; that of the manager, to general expense. No officer of the company other than the manager receives a salary. The help at the head office, other than the manager, consists of a bookkeeper and office boy.

In the case of another independent logging operation running four sides, the camp is directly in charge of a foreman who receives $175 per month. This foreman has an assistant who receives $125 per month. A logging superintendent, who spends practically all his time in camp, has general charge of the operation, the disposal of the logs, and the purchase of equipment and supplies. The camp office is practically the only office this company has, since all paper work is performed in the camp. This operation has a general manager, who, having a number of interests, does not give much attention to the affairs of the company. His salary is $1,000 per year. The salaries of the superintendent, foreman, assistant foreman, and bookkeeper are charged as camp expense.

In the case of another independent logging operation there is no general expense as far as general superintendence is concerned. A logging superintendent, who spends practically all of his time in camp, directs the operation. He is assisted by a felling and bucking foreman, a logging foreman, and a railroad foreman. These three men are directly responsible to the superintendent. The felling and bucking foreman directs the felling and bucking department; the logging foreman, the yarding and loading departments; and the railroad foreman, the construction and maintenance of the railroad. The superintendent has direct charge of the operation of the train. The superintendent receives $4,000 per year; the felling and bucking foreman, $125 per month; the logging foreman, $150 per month; and the railroad foreman, $125 per month. The salaries of the manager and foremen, as well as the salaries of the bookkeeper and scaler, are charged under the heading "Camp Expense." The company has no office other than that in the woods, and pays no salaries other than those mentioned.

In the case of an operation that both logs and manufactures, the logging camp is directly in charge of a camp foreman. This operation has an output of about 125,000 feet per day. A manager, who has general supervision of both the logging and manufacturing operations, receives $5,000 per year, one-half of which is charged against the logging.

GENERAL OFFICE EXPENSE.

General office expense may include clerical help, rent of office quarters, association dues, and the like. One bookkeeper, who is a stenographer, with possibly an office boy, should be ample help of this character for the largest independent logging operations.

TAXES.

Taxes on standing timber are frequently considered as an operating cost. Many operators, however, consider the tax on their timber as one of the costs of carrying stumpage. In connection with national forest timber appraisals this factor does not enter. Equipment and improvements are subject to taxation, regardless of where they are used or made, and so appraisals should always provide for taxes of this character. The system of taxation, also the rates, are discussed briefly in the section headed "Logging in General."

MISCELLANEOUS COSTS.

There are certain costs which may be grouped with or apart from general expenses; others should properly be so classed. The cost of workmen's compensation acts falls into the former class; the cost of fire protection, into the latter. Except as fire protection is maintained to protect woods equipment and improvements, it seems to be a charge for carrying stumpage rather than a logging cost. A considerable proportion of the fire fighting done by operators is, however, for the purpose of protecting equipment, improvements, and the like. Forest service timber sale contracts require each purchaser to use his employees in fighting fires on certain defined areas. The cost of this work may be properly included in the appraisal as a logging cost.

EXTRA COST OF LOGGING UNDER FOREST SERVICE REGULATIONS.

The preceding discussion of logging methods and costs, unless otherwise noted, is based on what is happening on private timbered areas. However, since the utilization of Douglas-fir stands within the National Forests is practically the same as that of similar stands on private lands, it applies for the most part to operations upon National Forests. There is this difference: Logging upon the National Forests is conducted under contracts with the Government, which provide certain regulations relative to cutting, utilization, logging, and fire protection. Compliance with these contracts ordinarily involves a little extra labor and thus adds to the cost of logging. For example, Forest Service timber-sale contracts dealing with Douglas-fir stands provide for the leaving of seed trees, from the base of which brush and other inflammable material is removed; the building of fire lines around certain areas, the felling of snags, the burning of slashings, the cutting of lower stumps, the utilization of more of the tops of the trees, and the logging of a higher percentage of the defective material than is ordinarily practiced in cutting private stumpage. The cost of this extra work varies from 8 to 15 cents per thousand feet.

TOTAL COST OF LOGGING AT ONE OPERATION.

The following deals with the cost of logging at a rather large operation in the Pacific Northwest during 1910, 1911, 1912, and 1913. Unless otherwise noted the discussion following the tables applies to 1912. It is impossible to discuss all the costs given. For the most part, the classifications are those of the operator.

CHARACTER OF COUNTRY.

Part of the area logged during 1912 is shown in figure 20. The country is mountainous, rough, and badly broken. The slopes in general are steep. No rock outcrops or cliffs were encountered. The streams are not of drivable size, but are so located as to make it unnecessary to pump water for long distances.

SOIL.

The soil is sandy loam with a clay subsoil. It drains poorly, making it necessary to gravel-ballast all spur railroads used for a year, also those used during the wet season. Practically all the ballast was hauled 3 miles.

OUTPUT.

The output for 1912 was as follows:

Species.	Scale.	Number of logs.	Contents of average log.
	Feet b. m.		*Feet b. m.*
Douglas fir	32,204,222	14,369	2,241
Spruce	829,157	494	1,667
Cedar	2,868,684	2,665	1,076
Hemlock	1,886,065	2,301	819
Total	37,788,128	19,829	....

Number of machine days	531
Average scale per operating day, feet b. m.	151,797
Average scale per yarding engine per yarding day, feet b. m	71,164
Average number of logs per yarding engine per yarding day	37
Average scale per log, feet b. m	1,904
Number of cars loaded	5,099
Average scale per car	7,410

Total cost of logging.

LABOR.

[Output, feet board measure. Cost per 1,000 feet.]

Items.	1910	1911	1912	1913
	16,722,000	26,605,000	37,788,000	41,870,000
1. Felling	$1.104	$0.313	$0.168	$0.230
2. Bucking	....	.457	.382	.390
3. Yarding	1.995	1.124	.746	.503
4. Roading and swinging	....	....	....	.040
5. Moving logging engines	....	....	.044	.080
6. Landing construction	....	....	.030	.090
7. Woods water system	....	....	....	.056
8. Pole-road construction	....	.046	.016	.016
9. Loading	....	.152	.112	.147
10. Spur railroad construction	.528	.313	.296	.467
11. Railroad maintenance	.346	.154	.189	.300
12. Railroad operation	.459	.152	.190	.180
13. Unloading	.110	.015	....	.009
14. Maintenance, locomotives and cars	.261	.187	.155	.100
15. Maintenance of logging engines and other equipment	....	....	.077	.126
16. Breakwater	.105	.013	....	....
17. Moving camp	.006	.006	....	.019
18. Office	....	....	....	.036
19. Camp management	.327	2.15	....	....
20. Miscellaneous	....	....	.031	....
Total	5.241	3.147	2.436	2.789

SUPPLIES, REPAIR PARTS AND MATERIALS, AND REPLACEMENT OF SMALL EQUIPMENT.

Items.	1910	1911	1912	1913
1. Wire rope	$0.495	$0.403	$0.180	$0.214
2. Rigging	....	....	.064	.045
3. Blocks and hooks	....	....	.021	.018
4. Fuel oil and supplies	.120	.066	.202	.256
5. Fuel wood, locomotives	.069	.028	....	....
6. Oil and grease	.040	.030	.027	.043
7. Waste and packing	....	....	.006	....
8. Powder	....	....	.048	.055
9. Shop supplies	.146	.088	.030	.051
10. Shop tools	.076	.045	.001	.027
11. Track and grading tools	....	....	.012	....
12. Miscellaneous tools	....	....	.001	....
13. Felling and bucking tools	....	....	.018	....
14. Woods water system, supplies	.017	.011	.005	.016
15. Ties	.052	.040	.050	.027
16. Miscellaneous supplies	.030	.021	.023	.040
17. Freight	.150	.080	.102	....
Total	1.195	.812	.790	.792

CAMP EXPENSES.

Items.	1910	1911	1912	1913
1. Rental right-of-way	$0.108	$0.069	$0.046	$0.022
2. Sorting and rafting (contract work)	.450	.450	.450	.450
3. Charity	....	....	....	.002
4. General	.053	.053	....	.003
5. Telephone	.002	....	.005	....
6. Boiler inspection, fire and liability insurance	.105	.064	.045	.050
Total	.718	.636	.546	.527

DEPRECIATION.

Items.	1910	1911	1912	1913
1. Main-line railroad grade	$0.149	$0.096	....	....
2. Track equipment	....	....	$0.038	$0.076
3. Logging engines	.101	.090	.041	.072
4. Locomotives	....	....	.059	.050
5. Rolling stock	.106	.060	.023	.038
6. Buildings and equipment	....	....	.012	.015
Total	.356	.246	.173	.251

GENERAL EXPENSE.

Items.	1910	1911	1912	1913
1. General management	$0.012	$0.092	$0.070	$0.081
2. Taxes	.072	.045	.040	.037
Total	.084	.137	.110	.118
Grand total	7.594	4.978	4.055	4.477

DISCUSSION OF LOGGING COSTS.

LABOR.

The cost of felling and bucking (1 and 2) in 1912 and 1913 includes the wages of the fallers, buckers, head bucker, and the assistant to the head bucker, also a portion of the camp supervision. In 1910 and 1911, an assistant to the head bucker was not employed, and the cost of camp supervision was classified under a separate heading.

The head bucker has charge of the felling and bucking, and, with the aid of an assistant, marks the trees into log lengths. The timber is large and the country rough, making the work of bucking hazardous. It is difficult to get the buckers to cut the logs the proper length, and the assistant to the head bucker has been found profitable. The log lengths are measured with a tape.

In 1912 the shortest logs cut were 16 feet long, but there were few cut shorter than 24 feet. A few 60-foot logs were cut, and a large number of 40-foot logs. The logs averaged about 32 feet in length.

During 1912 the operation averaged a little more than 3 sets of fallers and a little more than 16 buckers. In March there were 10 fallers and 16 buckers.

The wages paid in 1912 were as follows:

Head fallers	per day	$3.75
Second fallers	do	$3.40– 3.50
Buckers	do	3.25
Head bucker	do	3.75
Assistant to head bucker	do	3.00

It is the policy of the logging superintendent to bring the logging spurs close to the timber, so that it can be single-hauled (3 and 4) from the stump to the landing, unless the cost of constructing the spurs is excessively high or the operation of trains on them is impractical. Of course, other factors would influence him in deciding whether it was impractical to build a spur line to open up a body of timber. Figure 20 shows that much of the timber logged in 1912 was double hauled. This timber, as in the case of 1913, was hauled over the ground. The amount of double hauling done in 1913 is suggested by the labor cost, which appears as a separate item.

At the beginning of the year 1911 no timber was opened up except two small tracts, one of which had to be roaded and yarded a maximum distance of 7,500 feet; the other, a maximum distance of 4,000 feet. In both cases the timber had to be moved downhill. Later in the year other tracts were opened with pole roads and chutes, this timber being transported 5,000 feet at times. Fully 60 per cent of it was double hauled.

In 1912 and 1913 all the scalers' wages and a part of the camp supervision were charged against the cost of yarding and swinging. The following yarding crew was used in 1912:

Hooktender	per day	$5.00–$6.00
Head rigger	do	3.75– 4.25
3 riggers	do	3.00– 3.50
Sniper	do	3.00– 3.25
Chaser	do	3.00– 3.25
Signalman	do	2.50

At times it was deemed necessary to use four riggers besides the head rigger, also an extra chaser.

When double hauling was in progress, it was necessary to use the following additional men: Engineer, $3.50 per day; 1 or 2 chasers, $3.00 to $3.25 per day.

The above crews were employed when oil was used as fuel in the logging engines.

Moving logging engines (5) includes the cost of moving all logging engines, such as yarding, swinging, roading, loading, and power-scraping engines, from one site to another.

Landing construction (6) includes the cost of building eight landings. The cost includes clearing of site, constructing landings, digging engine settings, raising gin poles, and putting rigging on gin poles.

Woods water system (7) includes the cost of the laying of pipe lines and the pumping of the water for logging engines.

For loading the logs (9) in 1912 a gin pole, crotch line and grabs, and a double-drum loading engine were used. The loading crew during the major part of this year consisted of the following:

Engineer	per day	$3.25
Fireman	do	2.75
Head loader	do	3.75
Second loader	do	$3.25– 3.50

Firemen cut the wood for the loading engines, also started the fires in the roading or yarding engines, which burned oil. One-half of the fireman's wages was charged against the loading, the other half against the yarding. At times only one loader was charged against the loading, the chaser with the yarding crew doing the work ordinarily done by a second loader.

Spur railroad construction (10) includes the cost of clearing right of way, grading, laying the track, and ballasting the track with gravel. It is not possible to give the total length of spurs built in 1912. Three pieces of spur track, amounting to 6,800 feet, were built for $5,448, which is at the rate of $4,225 per mile.

Railroad maintenance (11) includes the cost of keeping all railroads in good condition as to surface and alignment, repairing trestles, keeping ditches open, taking care of slides, and digging and hauling gravel after the roads had been put in operation. In 1912 it includes the upkeep of about 6 miles of track. During this year section foremen were paid $3.50 per day; section hands, $2.50 per day.

Up to May 1, 1916, three locomotives (12) were used, two of which were geared 28 and 42 ton locomotives, and one a 22-ton direct-connected engine. During the remainder of the year another 42-ton geared engine was added, and the 22-ton direct-connected engine discarded. In 1912 the haul from the landings to the dump averaged about 6 miles. The conductor and brakeman, together with a man regularly employed at the dump, dumped the logs. The train crews in 1913 were as follows:

42-ton:		
Engineer	per day	$5.00
Conductor	do	4.25
Brakeman	do	3.75
33-ton:		
Engineer	do	4.50
Conductor	do	4.75
Brakeman	do	3.75

The locomotives burned oil.

Maintenance of locomotives, cars, logging engines, and other equipment (14 and 15). During 1912 20 flat cars and 6 sets of trucks were used. It is impossible to give the logging-engine days in logging, chunking-out, grading, landing, construction, gravel digging, loading, pile-driving, etc. The following machines were used during some part of the year: Four 10 by 13 inch; two 11 by 13 inch; one 9½ by 11 inch; one 9 by 10 inch; one 8½ by 10 inch; one 7 by 9 inch.

Three sides were operated until April 1; after that date two. Double hauling was done at different times during the year.

The regular shop crew was as follows:

Blacksmith	per day	$5.00
Blacksmith helper	do	3.50
Machinist	do	5.25
Machinist helper	do	3.25
Car tinkerer	do	3.25
Carpenter	do	3.50
Second carpenter	do	3.00
Rigging man	do	3.40

Camp management (19) includes the cost of camp foreman, timekeeper, bookkeeper, etc. During 1912 and 1913 this cost was prorated against the major department of the operation.

Wire rope cost includes the cost of the main hauling, trip, and main loading lines.

Rigging cost includes the cost of chokers, tag lines, crotch lines, straps, etc.

Powder cost includes the cost of the powder used both in yarding and railroad construction.